RADIO TO FREE EUROPE: ARMORED FORCE RADIO DEVELOPMENT,

GREAT BRITAIN AND THE UNITED STATES 1919-1941

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Communication provides the means for the commander to exert his or her personal will on the battle. The internal combustion engine's introduction greatly increased the complexity and reach of the commander's task, making instantaneous battlefield information, and hence radio communication, critical.

The tank's role was critical to radio employment because it dictated which communication system would be most useful for their control. The Germans devised a fluid system, and equipped it with radio distributed to the lowest practical level. In contrast, the British contemplated mobile warfare doctrine, but landed in France in 1939 with an infantry-based communications system. Their tank forces had never worked extensively with short-wave, and had no exposure to superior FM radio. The internal dynamics of the British Army, causing it to reject armored doctrine, obscured the power of radio communication applied to mobile formations. Additionally, external dynamics, including public sentiment toward the Army, public aerial bombing anxiety, economics, and the RAF's expansion also negatively impacted radio use at key points in the doctrinal work. The British effort to combine radio technology with an armored doctrine that fully exploited its use failed to answer the German challenge.

The United States Army adjusted more successfully. In 1942, its forces arrived in North Africa with a full complement of FM radios and a flexible communications

organization. American equipment and organization thus optimized voice command and control of armored warfare. Besides facing similar internal military dynamics and external societal influences, a certain amount of American success with radios was due to its later war entrance and superior resources. The major difference between the US and British responses, however, was in the public reaction to war's approach. The American public responded with the will to field an armored force and confront the German army on the ground.

This study principally contributes to the current historiography with its comparative look at US and British communications developments, its treatment of radio communications organizations, and the detailed look at the interwar evolution of such systems and radio equipment. The broad analysis of the societal and military factors influencing this evolution is an important secondary consideration.

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RADIO TO FREE EUROPE: ARMORED FORCE RADIO DEVELOPMENT, GREAT BRITAIN AND THE UNITED STATES 1919-1941

by

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INTRODUCTION

Communication is vital to military command. Commanders hunger for information: Where is the enemy? How many enemy troops are there? What are they doing? Where are our forces? Did we take the first objective? What should we do next? Late Air Force Colonel John Boyd described battlefield command as a cyclic process containing four fundamental tasks, observe, orient decide and act. The commander who operated the fastest OODA Loop, according to Boyd, would almost always defeat the opponent. Of the four tasks, communication is most crucial to observation and action. It provides the means for the commander to gain feedback from, and provide input to, the battlefield. In other words, communication allows the commander to exert his or her personal will on the battle.

Such a construct has always been applicable to warfare, but the introduction of the internal combustion engine has made information, and hence communication, even more critical. The airplane and the tank revolutionized warfare both by increasing the amount of firepower that could be brought to the battlefield, and by increasing the speed at which that firepower could be delivered.

Military practitioners perceived this change slowly as it emerged from World War I's trenches. They were slow to embrace aircraft and armored vehicles. They were even slower, in some cases, to realize that communications speed would have to make an exponential leap to accommodate them. For commanders to be effective in the new environment, they would still need to exercise personal control over the battlefield. However, soldiers no longer approached at a foot's pace or horse's trot, and troops no longer waited for the whites of their enemy's eye to attack. Commanders now had to coordinate tanks traveling at 30 miles per hour, infantry approaching the front in trucks, artillery firing over the horizon, and aircraft battling in the third dimension. Commanders

needed instantaneous personal communication, made possible only by radio equipment and a flexible command structure.

The tank's role was critical to the employment of radio because it dictated which communication system would be most useful. The Germans, who embraced the concept of a mobile armored force, devised a fluid system, and equipped it with short-wave AM radiotelephones distributed to the lowest practical level. Namely, platoon commanders would have two-way radios, and their subordinates, only receivers. Unlike the Germans, the British contemplated mobile warfare doctrine, but landed in France in 1939 with a World War I, infantry-based army and communications system. Their tank forces had never worked extensively with short-wave, and had no exposure to much superior FM radio. The internal dynamics of the British Army, causing it to reject mobile armored doctrine, obscured the power of radio communication when applied to mobile formations. In addition, external dynamics, including public sentiment toward the Army, public fear of aerial bombing, economics, and the RAF's self-aggrandizement also had a negative impact on the use of radio at key points in the doctrinal work. The British effort to successfully combine radio technology with a land warfare doctrine that fully exploited its use ultimately failed to rise to the challenge posed by the Germans.

The United States Army adjusted more successfully to the challenge posed by the internal combustion engine, and the Germans. Its forces arrived in North Africa in 1942 with a full complement of FM radios. Like the German system, platoon leaders had two-way radios, and individual tanks were equipped with receivers. The main US advancement was in the superior clarity and increased networking capability of the FM sets. With the formation of the Armored Force and the triangular infantry division in 1940, the Army also organized an inherently mobile communications system. Radiotelephone formed the primary links within the division, and between the division and Corps headquarters. American equipment and organization thus optimized the

conditions for voice command and control of armored warfare. In addition to facing similar internal military dynamics and external societal influences, a certain amount of credit for American success with radios belongs to its later entrance to the war and its superior resources. The major difference between the US and British responses, however, was in the public reaction to the prospect of war. The American public responded with the will to field an armored force and confront the German army on the ground.

This study documents the interwar evolution of British and American radio communications systems within their armored forces. It examines economic and public influences, as well as the effects of air force development and internal military conflicts. Also, a rather detailed look at radio technology helps explain some of the characteristics of the equipment, the significance of technical developments, and the difficulties associated with radio experimentation.

Of the relevant secondary literature concerning this topic, Delany Terrett's excellent *The Signal Corps: The Emergency* (Washington D. C., 1956), as part of the US Army in World War II series, covers the signal service's interwar experiences in significant detail. It looks at Army aircraft and ground radio development, as well as work on line communication and radar. Terrett's focus is technology advancement and procurement, with little emphasis on radio as a component of a communications system with a specific doctrine. The narrative began discussing tactical communications systems as they existed in 1939, and then chiefly focused on the technical shortcomings, rather than doctrinal ones. Terrett also acknowledged the importance of FM to tank warfare, and treated the events surrounding the army's acceptance of FM carefully. Efforts to devise a tank command and control system in the 1920's and early 1930's, however, received less attention.

Most of the other studies of the Signal Corps are based heavily on Terrett's work. The most substantial of these is Rebecca Robbins Raines' *Getting the Message Through:*

A Branch History of the US Army Signal Corps (Washington D. C., 1996). Her work mainly concerns Signal Corps organizational history, and scarcely mentions the technical side of their work. She devoted a portion of her chapter on the interwar years to research and development, including the army's use of FM for tanks, but she took her information directly from Terrett.

Other, even less important books either ignore the interwar years, as is the case with Max L. Marshall's *The Story of the US Army Signal Corps* (New York, 1965) and *A Concise History of the US Army Signal Corps* (Ft. Gordon, 1991), by Kathy R. Coker, or treat the Signal Corps in a celebratory manner, as do *A History of the US Signal Corps* (New York, 1961) and *What You Should Know about the Signal Corps* (New York, 1943). The scholarship on British interwar signals work is even more sparse, consisting mainly of a summary treatment in the British Army's *The Second World War, 1939-1945, Army: Signal Communications* (1950).

Discussions of armored doctrinal evolution is substantial on both sides of the Atlantic, but far more work exists on the British efforts. B. H. Liddell Hart's The Tanks Vol. I (New York, 1959) is perhaps the best known, and most detailed. Other, more credible, sources include Robert Larson's *The British Army and the Theory of Armoured Warfare, 1918-1940.* (Newark, DE:, 1984), Harold Winton's *To Change an Army*, and *The Sources of Military Doctrine: France, Britain, and Germany between the World Wars* (Ithaca, 1984), by Barry Posen. Of these, Liddell Hart and Winton treat radio the most thoroughly, but even they regard it as a secondary concern. Even the standard tank pictorial histories by Peter Chamberlain and Chris Ellis rarely mention radio, and when they do, types and capabilities are neglected.

For American work, the emphasis given radio is no better. The standard treatment is Mildred Hanson Gillie's *Forging the Thunderbolt* (Harrisburg, 1947), which provides a detailed, if hagiographic, look at Adna Chaffee's efforts with the mechanized cavalry.

Radio communication, if addressed, was simply mentioned as being good or bad. More recent work, including Christopher R. Gabel 's *The US Army GHQ Maneuvers of 1941* (Washington D. C., 1991), and *Seek, Strike, and Destroy: U. S. Army Tank Destroyer Doctrine in World War II* (Ft. Leavenworth, 1985), ignore radio altogether. Donald E. Houston paid the most attention to radio in *Hell on Wheels*.(San Rafael, 1977) Operational problems and successes were mentioned, but were accompanied by little comment. In all there seems to be a lack of appreciation among historians for radio's importance to tank forces, and their doctrinal development.

Broader looks at interwar military organization, such as Brian Bond's *British Military Policy between the Two World Wars* (Oxford, 1980), or *History of the United States' Army* (Bloomington, 1984) by Russell Weigley, are too broad to show specific impacts on radio development. In addition, no substantial look at signal organization evolution was found for either army, and therefore no comparative study of such a process exists.

Radio to Free Europe, therefore, principally contributes to the current historiography with its comparative look at US and British communications developments, its treatment of communications organizations as they relate to radio use, and the detailed look at the Interwar evolution of such systems and radio equipment. The broad analysis of the societal and military factors influencing this evolution is an important secondary consideration.

With these ideas in mind, the principal sources consulted were military field manuals, official government and military reports, military journal articles, newspapers, tech manuals, US Signal Corps Bulletins, relevant memoirs, secondary scientific and technical material, and published papers collections.

Chapter I

INTERWAR RADIO FOUNDATIONS

Radio Science and Technology to 1914

Because the technology and elementary physics behind radio are so central to the following discourse, a brief account of early radio technology and a discussion of terms will prove helpful. Radio as addressed in this study refers to the equipment allowing voice communication to occur through the manipulation and interpretation of electromagnetic waves. Although usually thought of in its commercial broadcasting manifestation, here it refers primarily to devices used to facilitate two-way, and occasionally one-way, battlefield communication. Early in its existence, radio was known alternately as radio, wireless telephony, or, most frequently, radiotelephony, and among British circles was typically abbreviated R/T. Its development was a direct outgrowth of wireless telegraphy, which utilized electromagnetic waves to communicate with the Morse dot-and-dash system. Wireless telegraphy was typically called wireless or W/T by the British, while Americans preferred radiotelegraphy, or simply radio. A problem emerges in examining the literature because of this confusion in terms. Most of the relevant British literature refers to all wireless communication, including radiotelephony, simply as wireless, and the American literature typically uses radio, though often more careful to indicate which type. As a result, determining which wireless method was being referenced during particular time periods and military applications is often difficult. However, clues such as standard operating procedures, equipment, and

employment make it possible to determine which method was intended with sufficient accuracy.

Wireless communication was an extension of the concept of long-distance communication first made practical by the line telegraph, invented in 1835 by Samuel F. B. Morse. By 1858, the British became the first to use a line telegraph to accompany soldiers in the field, beginning that device's long period of dominance in tactical communication.[1] Wire telephony was the next practical application to develop, but since the exact reproduction of sound (frequency, volume, and clarity) was more difficult, the telephone was not invented until 1876.[2] The scientific breakthrough behind wireless communication occurred in 1888 with Heinrich Hertz's experimental verification of James Clerk Maxwell's theories.

Maxwell's contribution to the understanding of electrical and magnetic phenomena is roughly equivalent to Isaac Newton's work in mechanics. In his four far-reaching equations, Maxwell summarized the work of Karl Friedrich Gauss, Michael Faraday, Andre Ampere and others, fully describing electro-magnetism. Significantly, Maxwell's equations controversially predicted the existence of electromagnetic waves propagating at a finite speed, the speed of light. The electromagnetic waves he predicted differed from light only by their energy level, as indicated by their frequency.[3] Visible

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[1]David L. Woods, *A History of Tactical Communication Techniques* (Orlando, FL: Martin-Marietta, 1965; New York: Arno Press, 1974), p. 107.

[2]Ellison Hawks, *Pioneers of Wireless* (London: Methuen, 1927; New York: Arno Press, 1974), p. 96.

[3]Electromagnetic waves are transverse waves, meaning they oscillate in the plane perpendicular to their direction of motion. They can be visualized by imagining the surface of an ocean wave traveling past a fixed point. The distance between the crest of one wave and its successor is the wavelength (λ), and the time period necessary for these two successive crests to pass the same point is the period (T). Frequency, then is the inverse of the period ($f = \frac{1}{T}$), and is expressed in terms of cycles per second, or Hertz (Hz). The velocity of the wave is, naturally, distance divided by time, or $v = \frac{\lambda}{T}$. The relationship between frequency and wavelength follows, and is expressed as $v = f\lambda$, where, in the case of electromagnetic waves, the velocity is the speed of light, c.; Raymond A. Serway, *Physics: For Scientists and Engineers with Modern Physics* 3d ed. (Philadelphia, PA: Saunders College Publishing, 1990), p. 442.

light has frequencies on the order of 10^{15} Hertz (Hz) with wavelengths less than 1 micron. Radio waves occupy a lower position on the spectrum, roughly between 10^5 and 10^8 Hz, with wavelengths ranging from about 1 kilometer to 1 meter.[4] The equations also predicted the generation of these waves whenever electrical charges were accelerated. Seeking to provide firm proof of the existence of Maxwell's predictions, Hertz developed a method of generating and detecting electromagnetic waves propagating through free space, and by doing so, laid the foundations of radio communication.[5]

Hertz's first requirement was to devise a way of producing electromagnetic waves of known frequency. He based his transmitter on the Leyden jar, an early capacitor consisting of a glass jar coated with foil on its outer and inner surfaces.[6] Capacitors store energy by creating an electric field between two oppositely charged plates separated by an insulating medium, in this instance the glass jar. If the two foil surfaces were connected, the electricity stored in the Leyden jar would be discharged in the form of a spark. The spark appeared singular to the naked eye, but actually was a series of rapidly oscillating electron streams resulting from the oscillation of the relative negative and positive plate charge. To create a predictable frequency, Hertz would need another common electrical device, the inductor. Inductors store energy in the form of a magnetic field, which is created when electric current is run through a tightly wound coil of wire.[7] When connected in series, inductors and capacitors alternately store and discharge energy

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[4]Ibid., p. 973.

[5]Hugh G. J. Aitken, *Syntony and Spark: The Origins of Radio* (Princeton,NJ: Princeton UP, 1985), pp. 31-32.

[6]Ibid., pp. 54-55.; Capacitance is a function of the area of the two parallel metal surfaces and the distance between them ($C = \frac{\varepsilon_0 A}{d}$), where C is capacitance, A is the plate area, and d is the separation distance.; Serway, *Physics*, p. 712.

[7]Inductance is determined by the number of turns in the wire coil and the electric current flowing through it ($L = \frac{N\phi_m}{I}$), where L is the inductance, N the number of turns, and I the current.; Ibid., p. 918.

with an easily determined oscillation frequency.[8] Hertz's transmitting circuit, therefore, consisted of a battery powered inductor, and a capacitor in the form of a spark gap and two metal plates. When connected, the circuit generated electromagnetic waves at the spark gap, and transmitted them through the plates, which functioned as the antenna.

Hertz detected the oscillations produced with a crude device called a circular resonator, which was simply a metal hoop interrupted by a spark gap. The resonator was "tuned" by adjusting its circumference to resonance with the transmitter, the point at which the strongest spark could be induced across its gap. While effective enough for Hertz's experiments, this device contributed less to the eventual success of wireless communication than did the spark transmitter.[9]

The groundbreaking progress enabling the reception of electromagnetic signals was accomplished by Oliver Lodge. Working at roughly the same time, Lodge conducted similar experiments using wires to transmit the electromagnetic waves. While offering equally convincing validation of Maxwell's equations, Lodge's work offers no evidence that he made the conceptual leap to transmitting and receiving waves across empty space, thus leaving that distinction to Hertz. Lodge's major contribution to radio development was his discovery of tuning and coherence. In the year following Hertz's demonstration, Lodge conducted his "Syntonic Jar" experiments, first demonstrating circuits that could be syntonized, or tuned.[10] The setup consisted of two Leyden jars, one of which operated similarly to Hertz's oscillator, keeping the jar in the circuit instead of substituting the dipole antenna. The other Leyden jar had its outer and inner foils linked by a spark gap and an adjustable wire loop. When the transmitting jar was powered, the receiving jar

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[8] $\omega = \frac{1}{\sqrt{LC}}$, where ω is the angular frequency.; Ibid., p. 919.

[9] Aitken, *Syntony and Spark*, p. 56.; Oliver J. Lodge, *Signalling across Space without Wires: Being a Description of the Work of Hertz and His Successors*, 3d ed. (London: "The Electrician" Printing and Publishing Co.), p. 8.

[10] Blake, *History of Radio Telegraphy and Telephony*, p. 99.

could be tuned by adjusting the length of the wire loop until a spark appeared across the spark gap. The Syntonic jar was the prototype of most early radio receiving circuits.[11]

Also in 1889 Lodge's experiments led to the observation that "two knobs sufficiently close together could, when a spark passed through them, actually cohere," meaning that in the presence of low current the knobs would not be capable of transmitting electricity, but when higher voltage was present, they would join together and remain so until separated.[12] Coherence, then, is a reduction of resistance to electrical current observed in the face of electromagnetic waves of sufficient strength. It allows for sensitive detection of electromagnetic waves, the most fundamental property of a radio receiver. Eduard Branly produced the first practical coherer in 1890. His device was a glass tube filled with iron filings that in the absence of Hertzian waves proved highly resistant to current. When electromagnetic waves were present, however, the filings would cohere, greatly improving the device's conductivity. To detect the next incoming signal, the device had to be reset physically with a light tap.[13] Lodge had independently devised a similar device, but, unlike Branly, he saw its utility for the reception of Hertzian waves. Lodge, however, did not recognize the potential implications for a communication system until William Crookes floated the possibility in an 1892 journal article.[14] By 1894 Lodge had demonstrated a working radiotelegraph at the Royal Institution, but was temporarily disinclined to pursue the commercial applications.[15] His hesitancy provided the only opportunity Italian inventor Guglielmo Marconi needed to step to the forefront of wireless development.[16]

In 1896, Marconi arrived in Britain with the first practical wireless telegraph. It employed an improved version of Hertz's oscillator for a transmitter, and an improved

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[11]Ibid., p. 100.
[12]Lodge, *Signalling across Space without Wires,* p. 20.
[13]Ibid.
[14]Aitken, *Syntony and Spark,* p. 111.
[15]Blake, *History of Radio Telegraphy and Telephony*, p. 106.
[16]Aitken, *Syntony and Spark,* p. 179.

Branly coherer for its receiver. In 1900, he patented a tuning system basically stolen from an idea Lodge had patented in 1897.[17] While not a conceptual pioneer, Marconi excelled at experimentation, innovation, and business. As a result of these talents, he quickly established himself as the major supplier of radio equipment for Britain, and his company took upon itself the operation of the Empire's commercial wireless system. The elements that made Marconi's set practical were longer, land-grounded aerials, and a specially constructed transformer.[18] Since the length of an aerial corresponded to one quarter of the transmitted signal's wavelength, larger antennas allowed the use of longer wavelengths, which exhibit properties more conducive to long-range transmission. Higher frequency waves, such as those produced by Hertz, behave very much like light, making them more susceptible to obstruction by ground objects, and allowing them to pass unimpeded through the ionosphere. Until the advent of short-wave radio, Marconi and others pursued ever greater transmission distances by lowering frequencies. When they reached the practical limits of antenna size, they boosted range through ever larger power outputs.[19]

Marconi's early sets all employed spark transmitters, capable of transmitting only one ill-defined frequency and only crudely tunable. In sparsely populated aether, such a characteristic was not a major consideration, but mutual interference would make it impossible to operate a large number of sets in the same area. For those seeking military and naval applications, the need for more precise tuning and variable transmission frequencies was paramount. Spark transmitters also produced rather choppy signals, and the need for mechanically resetting the coherer after each dot or dash rendered them much slower than wire telegraphy. Early wireless, while a significant advancement in

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[17]Ibid., p. 142.
[18]W. J. Baker, *A History of the Marconi Company* (London: Methuen and Co., 1970), p. 59.
[19]Aitken, *Syntony and Spark*, p. 197.

communication technology, would need a great deal of refinement to become practical for military field use.

Wireless technology was also a long way from allowing voice communication over the air waves. The inherent sparking noises caused by the oscillating charge of the spark transmitter made voice transmission impossible because they obscured the desired signal. Radiotelephony would be impossible until a new way of transmitting emerged in 1902.[20] The continuous wave, or Poulsen Arc transmitter was developed by Valdemar Poulsen, but did not become widely available until 1911. Poulsen was actually improving a direct current arc invented by W. Duddell in 1900. Duddell created a circuit that connected an inductor and a capacitor in series, which he connected in parallel with a spark gap. By running a direct current through the circuit, the inductor-capacitor combination generated a continuous arc with a sinusoidal modulation across the spark gap.[21] Unfortunately, the modulation frequency was not rapid enough to produce radio waves. Poulsen's contribution was to place the spark gap in hydrogen, which along with other modifications, allowed the device to produce radio band frequencies. Using the Poulsen Arc, it became possible to produce frequencies as high as 500 kHz with roughly a kilowatt of power.

To add voice information to the sinusoidal wave produced by the Poulsen Arc, an audio signal would be introduced, changing the amplitude of the original wave. Transforming voice into an electrical signal had been accomplished many years before with the invention of a microphone for wire telephony. For radiotelephony, a microphone would be connected to an inductor that would be coupled with the inductor in parallel with the spark gap. By talking into the microphone, the audio signal would influence the inductance, which in turn conveyed the audio signal to the sinusoidal

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[20]Blake, *History of Radio Telegraphy and Telephony*, p. 177.
[21]Ibid., p. 159.

wave.[22] When used to carry an audio signal, the sinusoidal wave is known as a carrier wave. The audio signal directly alters the carrier wave, meaning that degree of amplitude change represents the audio volume, and the rate of amplitude change represents pitch. The louder the audio signal, the larger the amplitude change, and the higher the audio signal, the faster the amplitude will change within the limits set by the volume. This is known as amplitude modulated radio (AM), and would remain the dominant means of military radio communication through the Second World War.

Radiotelephony became possible with the continuous wave transmitter, but because continuous wave production required a great deal of power and bulky apparatus, it would take another major advancement to bring radio to the battlefield, even in its crude World War I form. Lee DeForest's 1906 three-electrode valve, or audion, holds the distinction of revolutionizing the transmission of continuous waves, though it was used exclusively in receivers until 1913.[23] DeForest's invention, actually an improvement on Ambrose Fleming's 1904 two-electrode valve, was a partially evacuated glass tube containing a filament, a metal grid connected to a receiving aerial, and a metal plate. They were arranged so that the grid was positioned between the filament and metal plate. When current flowed through the filament, electrons would be attracted to the relative positive charge on the plate, producing a detectable current across the valve. The grid, meanwhile, would receive electrons from the aerial, leaving it more or less negatively charged in correlation to the incoming signal. Remembering that like charges repel and opposite charges attract, the grid tended to attract or repel the electrons coming from the filament, thereby influencing the current across the valve.[24] In this way the audion slightly amplified the incoming radio signals, a function that the Fleming valve, lacking the grid, could not.

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[22]Ibid., pp. 176-177.

[23]Hawks, *Pioneers of Wireless,* pp. 268, 277.

[24]John Scott-Taggart, "The Use of Vacuum Tubes for Wireless Transmission and the Reception of Continuous Waves," *Institution of Electrical Engineers Journal* (1920): 893.

The reception qualities of the audion were greatly enhanced by the use of the regenerative circuit, invented by Edwin H. Armstrong in 1913. The regenerative circuit worked by taking the output current coming from the audion's plate circuit and feeding part of it back through the grid circuit. In this way, the regenerative circuit could amplify the original signal about one thousand times. In one of the more important cognitive steps in radio evolution, Armstrong also noticed that at the highest amplification level the audion produced a hissing noise with a beat frequency, and realized that the audion itself was functioning as a source of high frequency continuous waves.[25] Later that year, the Marconi Company patented a three-electrode valve in which the plate circuit and mesh were "electrostatically coupled," producing continuous oscillations.[26] Coupling was accomplished by attaching an inductor and a power source to the mesh circuit, and the familiar inductor-capacitor oscillating circuit to the plate circuit. When current was run through the filament, the rush of current to the plate circuit caused the inductor-capacitor circuit to oscillate. Under normal circumstances the resistance inherent in the wires would cause these oscillations to die out. However, the mesh circuit perpetuated the oscillation by providing perfectly timed bursts of current.[27] Marconi's device, utilizing Armstrong's regenerative principle, provided a compact, efficient, means of producing continuous waves of radio frequency, making field radiotelegraphy possible just in time for the Great War.

British and American Wireless during the Great War

While radiotelephony was now, in theory, available for field use, neither the British nor the American Army employed it on a large scale during World War I. When

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[25]Lawrence Lessing, *Man of High Fidelity: Edwin Howard Armstrong* (Philadelphia, PA: J. B. Lippincott, 1956), pp. 67-68.; Rights to the regenerative circuit, also called the feedback or retro-active circuit, have also been claimed by DeForest, who actually holds the patent, Irving Langmuir, and Alexander Meissner.; Blake, *History of Radio Telegraphy and Telephony,* p. 260.

[26]Hawks, *Pioneers of Wireless,* p. 277.

[27]Scott-Taggart, "The Use of Vacuum Tubes," p. 59.

Great Britain went to war in August of 1914, it became evident that civilian technological advancements could not translate directly to military utility. If the British Army was to employ radio on a large scale, it would have to design and mass-produce relatively complex and delicate instruments suited to each need, at a time when it could barely manage the immense difficulty of fielding and equipping a fighting force of unprecedented size. Chief among the components causing mass-production difficulty were vacuum tubes. Achieving the desired level of evacuation required special molecular pumps, each capable of processing only one tube at a time. To ensure uniform electrical characteristics, tolerances were confined to within a small percentage of the separation distances within the tubes.[28] As a consequence, the British produced most of their early equipment from widely available components, meaning that spark sets would see immediate use, and sets transmitting continuous waves would have to await further development. When radio communication was attempted it was almost always in the form of wireless telegraphy. The Royal Navy and Royal Flying Corps made the most consistent use of this limited capability, and in a foreshadowing of things to come, received production priority from the government.[29] As an emergency measure, the government even installed gigantic Poulsen Arc transmitters on most of the Navy's major vessels by late 1916. For aircraft and field sets, however, size and weight were premium, and continuous wave use would not be possible until suitable valves could be manufactured. The Royal Flying Corps attempted to use soft, or partially evacuated, valves in April 1916, but the cold temperatures at altitude made them prone to failure. Suitable hard, or fully evacuated, valves were not available until late 1918, and saw only limited employment before the war ended.[30]

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[28]U. S., War Department, *Annual Report of the Chief Signal Officer: To the Secretary of War* (Washington, D. C.: U. S. Government Printing Office, 1919), p. 267.

[29]Guy Hartcup, *The War of Invention: Scientific Developments, 1914-1918* (London: Brassey's Defence Publishers, 1988), p. 76.

[30]Ibid., pp. 128, 153.

The Army, meanwhile, began to experiment in 1915 with borrowed Flying Corps spark wireless sets. These experiments included command exercises during which the corps, battalion, brigade, and division headquarters were issued wireless, the corps set being placed in a truck. They also successfully attempted forward artillery observation by placing a wireless set in an observation balloon, from where it transmitted shell-fall coordinates to cooperating artillery batteries.[31] By June 1916 British observer and close support pilots were receiving training for the operation of wireless. The British gradually refined this system, their ability to range enemy trench systems greatly facilitating trench strafing and artillery attacks.[32] Artillery spotting was an important application, but the main communication problem for the army was the desperate need to maintain line communication between headquarters and advancing infantry. The static conditions on the Western Front gave rise to elaborate wire telephone and telegraph systems in the rear areas, but attempts to extend wire across the trench lines never led to satisfactory results. Extending wires by means of signal troops hauling backpack wire carriers was unreliable, and even if the soldiers managed to lay the wires, artillery fire often severed them. Spark sets, while not requiring skilled operators because they did not need tuning, and remained heavy, cumbersome, and prone to failure.

While these characteristics were discouraging, the army continued to seek a solution to its forward communication problems, and spark sets were decidedly better than nothing. It managed to deploy three different types of spark sets by the end of 1916. The first, known as the BF Set, was inspired by the army's earlier command exercise, and required 50 watts to transmit between 4,000 and 10,000 yards. It was unpopular with the men because it was unreliable, it often required the use of a cipher, required up to six men to carry it, and perhaps most disturbing, its aerial drew gunfire. The second set

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[31]Woods, *Tactical Communication Techniques*, p. 225.

[32]Hubert C. Johnson, *Breakthrough!: Tactics, Technology, and the Search for Victory on the Western Front in World War I* (Novato, CA: Presidio Press, 1994), pp. 149-155.

represented no significant improvement on the first. However, the third, the so-called Loop Set, was easier to carry and used a smaller, looped antenna. It could transmit a maximum of 2,000 yards and, like its contemporaries, was of questionable reliability. A continuous wave set finally reached the trenches in 1917. It could transmit about 6,000 yards, was two-man portable, and transmitted on a more precise frequency than its spark predecessors. By 1918, the British saw wireless as a reliable backup for line communication in the field, but forward units were plagued by mutual interference and lack of transportation for the rapidly multiplying sets.[33]

Like field wireless, the practical radiotelephone also awaited the introduction of suitable valves, but the advantages of such systems were obvious to the Flying Corps and Tank Corps. In February 1916, the Flying Corps had experimented with radiotelephone for air-to-ground communication, but the valve problem would delay the project until 1917, after which two squadrons received radios.[34] Also in 1916, E. D. Swinton, an amateur theorist with War Office connections, outlined a primitive doctrine for tank use in support of infantry. When the infantry began its advance, tanks were to emerge from hiding and attack, communicating with each other by visual signals, and receiving direction from headquarters through radiotelephone receivers.[35] Until available, however, wireless telegraph would have to be used in its place. Fittingly enough, the first experiment with wireless tank control occurred at Cambrai on 16 November 1917, the first large-scale tank offensive. The British tanks for this offensive were primarily Mk IV males. These machines were improved versions of the original 28-ton rhomboid tanks introduced in 1916. The male version was armed with two six-pound guns for assaulting enemy artillery and fortifications, and capable of 3.7 miles per hour. The British also employed Mk IV females, which wielded 5 machine guns to cover the male's advance,

[33]Woods, *Tactical Communication Techniques*, pp. 225-227.
[34]Hartcup, *War of Invention,* p. 154.
[35]Johnson, *Breakthrough!*, p. 164.

and mop up enemy infantry. It was an early version of this tank that became the first to be equipped with a wireless set.[36] Otherwise unarmed, the Mk I Wireless Tank carried a huge aerial mast with eight antenna wires strung down to the tank body. Employed in conjunction with wire-laying tanks for line communication, the Wireless Tank was only marginally effective at Cambrai and subsequent battles.[37] As the offensive was only a limited success, Cambrai demonstrated that tanks would not break the stalemate on their own, and the Army increased efforts to develop doctrine incorporating all arms in offensive actions.

Communications between the various arms during coordinated action posed a major problem. Early on, British tank commanders entered battle in the leading tank, and while personal command was better than command from the rear, decisive liaison with the accompanying infantry was especially difficult.[38] Radiotelephone was an obvious answer if it could be made to work, but no headway was made until after the war. After unsatisfactory battlefield experience using the Wireless Tank for infantry liaison, tank commanders entered the Battle of Amiens in August 1918 riding horses or swift Whippet tanks. Tank cooperation with aircraft did not fare much better. In early 1918, one of the two radio-equipped air squadrons was assigned to the Tank Corps for cooperation experiments, but the June tactical papers still specified flares as the accepted method of air-tank liaison.[39] Wireless telegraph was too inflexible, and radiotelephone too "hopelessly crude" to coordinate combined arms assaults, forcing reliance on older communication methods like messengers and visual signals.[40]

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[36]Peter Chamberlain and Chris Ellis, *Pictorial History of Tanks of the World, 1915-1945* (Harrisburg, PA: Lionel Leventhal Limited, 1972), pp. 68-70.

[37]Johnson, *Breakthrough!,* p. 204.

[38]Martin Blumenson, *The Patton Papers, Vol. 1, 1885-1940* (Boston, MA: Houghton Mifflin Co., 1972), p. 597.

[39]Johnson, *Breakthrough!,* pp. 251, 264.

[40]"Wireless Development During the War," *Electrical Review* (18 April 1919): 438.

As latecomers to the war, the Americans had little time to experiment with radio communication. When the United States entered on 6 April 1917, officials estimated that forces could be mobilized, equipped, and in France ready to take the offensive no earlier than 1919.[41] The Germans, anticipating the shift in the strategic balance, decided to use the opportunity to launch a war-winning offensive in the Spring of 1918. Fearing collapse, the British and French increased demands for immediate American participation, compelling the American Expeditionary Force (AEF) to enter battle earlier than anticipated. This, coupled with inefficient economic mobilization, compelled the AEF to supplement its meager equipment with that of the Allies. Two-thirds of the aircraft, all but a handful of artillery, and all the tanks were of Allied manufacture.[42]

The US Tank Corps, commanded by Brigadier General Samuel D. Rockenbach, was deployed in both the British and the American sectors of the front. One battalion operated about 50 British heavy Mk V tanks, and fought in the British sector. The other two battalions were equipped with Renault FT Light Tanks of French design.[43] The Renaults had a two-man crew, were armed with an 8 mm Hotchkiss machine gun, and could travel 5 miles per hour on prepared surfaces, or 1.5 mph cross-country.[44] These two battalions of about 72 tanks each were organized as the 304th Tank Brigade, and placed under the command of Lieutenant Colonel George S. Patton. Following their allies' example, the Tank Corps deployed its forces in close support of infantry. Patton's command experience in this role reveals the extreme difficulty faced in trying to effect tank-infantry control, even with tanks only marginally capable of outpacing humans on the battlefield. The Renault tanks were too small to allow the commander to ride into

[41]Allan R. Millett and Peter Maslowski, *For the Common Defense: A Military History of the United States of America, Revised and Expanded* (New York: The Free Press, 1994), p. 351.

[42]U. S., War Department, *Final Report of General John J. Pershing: Commander-in-Chief American Expeditionary Forces* (Washington, D. C.: U. S. Government Printing Office, 1919), pp. 74-76.

[43]*Final Report of General John J. Pershing*, p. 76.; Chamberlain and Ellis, *Tanks*, p. 72.

[44]Robert E. Rogge, "The 304th Tank Brigade, Its Formation and First Two Actions," *Armor* (July-August 1988): 27.

battle, as practiced by the British in their larger models. The best methods available were runners, and in an emergency, pigeons.

As Brigade Commander, Patton was theoretically supposed to stay at Brigade Headquarters and stay in contact with Rockenbach by line telephone. However, the tactical situation and, to some degree, Patton's disposition, made this impractical. In the 304th's first action at the Battle of St. Mihiel starting 12 September 1918, Patton found himself compelled to accompany the tanks on foot, coordinating advances personally, or by runner. Two days later, Patton again found himself in the field with the tank, and out of touch with headquarters, which he had left entrusted to an aide. While Patton had performed admirably, and the 304th had greatly assisted 1st Infantry Division, his absence understandably upset Rockenbach, who resented being eliminated from the chain of command. For the next engagement, he unequivocably ordered Patton to remain at his brigade headquarters. When the 304th, now redesignated the 1st Tank Brigade, next saw battle during the Meuse-Argonne Offensive starting a few days later, Patton was again unable to stay at headquarters, and was seriously wounded directing an infantry advance in the wake of his tanks.[45] The existing method of control was obviously inadequate, but no suitable radio sets existed in Allied inventories, and the American-designed tank radiotelegraph, the SCR-78A, was not available before the end of the war.[46]

As was the case with tanks, field artillery, and aircraft, America's short lead time also forced the AEF to use Allied communications equipment. In March 1918, the Signal Corps had to rush French-made radios into French-made SPAD aircraft using contracted French labor in order to field the first Air Service observation squadron. When the First American Army was formed on 26 August 1918, it organized all of its radio nets based on the French model, and used its ally's equipment exclusively. The same applied to the Second American Army upon its formation. The wealth of experience gained by its ally

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[45]Blumenson, *Patton Papers, Vol. 1*, pp. 583, 588, 587, 612.
[46]*Annual Report of the Chief Signal Officer*, p. 256, 310, 324-325.

during four years of trench warfare was both desperately needed and stifling to experimentation. When the Signal Corps finally organized the Radio Service October 1918, it saw communications intelligence as its principal mission. Army radio troops focused on intercepting German messages, and manning radio direction-finding posts to locate German communications centers. Other functions included in the Radio Service sphere of responsibility included supervision of Air Service radio, training of artillery radio operators, and field testing new equipment.[47]

Besides the rapidity with which the war unfolded for the Signal Corps, experience had done little to prepare its leaders for the type of war it would fight in Europe. The 1916 Punitive Expedition against Mexico was the first American experience with wireless in a military operation. Commanders had spark sets packed on mules and wagons at their disposal, but the tactical situation allowed them to rely on more traditional communication methods, which natural tendencies favored.[48] By this point, the Signal Corps had been working with radios for thirteen years, but its research and development program was less than inspired. Its best work prior to 1916 had in fact been the 1912 fielding of the cavalry pack set deployed in Mexico. Attempts at a longer range set had met with failure, and the Army had to procure an equivalent set from Germany.[49]

Once war with that country seemed inevitable, however, the Signal Corps took steps that would make its research and development effort its most important contribution to future radio.[50] In late 1916, collaboration with General Electric and other corporations produced research on vacuum tubes designed so that one battery could power both the plate circuit and the filament. By the time the United States declared war, the Signal Corps had several prototype vacuum tubes that were ideal for field use, and when needed,

[47]Ibid., p. 310.

[48]Dulany Terrett, *The Signal Corps: The Emergency*, United States Army in World War II (Washington, D. C.: Office of the Chief of Military History, Department of the Army, 1956), p. 16.

[49]*Annual Report of the Chief Signal Officer*, p. 217.

[50]Terrett, *The Emergency*, p. 18.

could be easily mass-produced. Partially as a result of this step, the Signal Corps produced a wide variety of radiotelegraph and radiotelephone sets, including three varieties of aircraft radiotelephone sets, a field radiotelephone set, and the tank radiotelegraph. While too late to have an impact on the war, these sets represented a number of key innovations.[51]

By far the most important of these was the superheterodyne receiver. Now a Captain in the Signal Corps, Edwin Armstrong refined his regenerative method of amplifying high frequency continuous waves into the master oscillator power amplifier (MOPA).[52] Before the end of the war, he tested an experimental radio set for tank communication on the MOPA, and had begun incorporating it into his superheterodyne receiver. The superheterodyne was the application of the heterodyne principle to high frequency continuous waves. Conceived in 1902, but not fully developed until 1907, R. A. Fessenden's heterodyne principle represented a promising way to improve signal reception by combining an incoming signal with a local signal of nearly equal frequency. The result was an amplified beat frequency equal to the difference between the two primary frequencies. The resultant beat frequency would also retain the amplitude modulated information sent with the original signal. The applicability of this principle was severely limited by the lack of a reliable high-frequency oscillator, which Armstrong remedied with his 1913 invention of the vacuum tube regenerative circuit.[53]

The superheterodyne receiver runs the incoming signal through four stages, each of which require at least one vacuum tube. The first stage, called the mixer, takes high frequency signals and heterodynes them with a local signal produced by an oscillator tube. The resulting beat frequency, or intermediate frequency, continues to stage two, where a regenerative circuit amplifies it three or four thousand times. Stage three detects

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[51] *Annual Report of the Chief Signal Officer*, pp. 219, 247-248.
[52] Terrett, *The Emergency*, p. 19.
[53] Lessing, *Armstrong*, pp. 104-105.

the amplified signal and converts it to direct current. The final stage further amplifies the signal to levels capable of actuating a speaker.[54] The principal value of a superheterodyne receiver was that it enabled the reception of radio waves of extremely high frequency, namely, those above 100,000 Hz.[55] High frequency waves were weak and difficult to detect, even with the regenerative circuit, which could only amplify up to the point that its vacuum tubes began to oscillate themselves. Even stringing several tubes together in a regenerative arrangement only allows the detection of frequencies lower than 1,500,000 Hz.[56] By allowing the reception of frequency in the Mhz range, the superheterodyne set the stage for short-wave radio and frequency modulation, the two major radio innovations that would emerge before the next war.

The German Model

The reason radio intelligence and direction finding had been so lucrative for the Allies during the war was the wholesale German acceptance of radio as a means to relieve their congested line systems. Wireless allowed them to transmit orders directly to a large number of units without the inefficiency inherent in forcing messages through line relays and switching stations.[57] The Germans retained their acceptance of radio communication throughout the interwar period, and World War II, seeing it as the ideal means to wed their command philosophies with the emerging mobile style of warfare.

The groundwork for German armored warfare doctrine was laid by General Hans von Seeckt, the head of the *Truppenamt* for the *Reichswehr* from 1919 to 1926.[58] Von Seeckt's *Reichswehr* had to prepare for mobile warfare due to its small size and the

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[54]Ibid., p. 112.

[55]100,000 Hz or 100 kHz is just below the range of modern AM radio, which starts at 530 kHz.

[56]Lessing, *Armstrong,* p. 104.; 1,500,000 Hz or 1.5 Mhz is well below the FM transmission range, 87.5 MHz-108.0 MHz.

[57]Alan Beyerchen, "From Radio to Radar: Interwar Military Adaptation to Technological Change in Germany, the United Kingdom, and the United States," in *Military Innovation in the Interwar Period,* ed. Williamson Murray and Allan R. Millet (Cambridge, UK: Cambridge UP, 1996), p. 266.

[58]Charles Messenger, *The Art of Blitzkrieg,* (London: Ian Allen Limited, 1976), p. 56.

geographical necessity of anticipating a two-front conflict. The majority of this strategic and tactical thinking was summarized in *Leadership and Battle with Combined Arms*, published by the General Staff in 1923.[59] Germany's tactics were thus largely established soon after the war, with subsequent work constituting refinements rather than revolutionary changes. Heinz Guderian, the noted armor expert, proved influential at this point, realizing the futility of using tanks to support infantry units. By 1935 he had developed the concept of the *Panzer* division, which employed the other combat arms subordinately, subject to the speed and mobility of armor. Army doctrine gained the further advantage of Hitler's enthusiastic approval, since it meshed with his conviction that infantry assaults were obsolete, and that future wars would be won by quick, decisive blows.[60]

The equation for *Blitzkrieg* also required the decisive addition of tactical airpower. In 1920, a group of fighter commanders made its recommendations to von Seeckt's *Truppenamt*. These included the need for unity of command within fighter squadrons, made possible by two-way radio communication. At the expense of a viable strategic doctrine, the *Luftwaffe* emerged as tactical force, concentrating on cooperation with the army. Documents surreptitiously published in 1925 and 1926 outlined the future aircraft functions of what would become the *Luftwaffe,* including deep battlefield interdiction, close army cooperation, and escort and air superiority duties. They also assigned artillery observation and reconnaissance aircraft directly to each division.[61] For cooperation with ground forces, the Luftwaffe relied on a combination of wire telephony and wireless. Air Fleet Headquarters would be located near that of the cooperating Army Group. The forward air controllers, traveling with the most advanced units of ground troops radioed back to Air Fleet Headquarters, which in turn notified subordinate units of the new

[59]James S. Corum, *The Roots of Blitzkrieg: Hans von Seeckt and German Military Reform* (Lawrence, KS: University Press of Kansas, 1992), p. 199.

[60]Ibid., p. 58.

[61]Ibid., pp. 147, 153.

information either by radio or wire links. As aircraft reached the front, the forward air controller would gain control over them, and direct them to their targets by voice.[62] The Panzer divisions of Hitler's rechristened *Wehrmacht* emerged as a self-sufficient combined arms team, with light and medium tanks, cooperating air units, motorized infantry, engineers, mechanized reconnaissance elements, artillery, and signal units.[63]

The importance of effective radio communication in German military thought was apparent early in the Army's effort to rebuild after World War I. German civilian firms actively pursued short-wave radio development in the 1920's, and by 1927 Germany led the world in this technology. Beginning in 1924, German armor experts, specifically Guderian, mandated that every tank developed had to provide for the installation of a radio.[64] The Germans thus recognized the importance of radio even before they had developed a solid armored warfare doctrine. In addition to his talents as a mobile warfare theorist, Guderian was also an expert on wireless communication. During World War I, he had functioned as an upper-level Signals Officer, gaining first hand knowledge of the flexibility afforded to units employing wireless.

Guderian's idea of command was a continuation of Prussian military tradition, relying on the personal initiative of the commander. According to the forward command doctrine, individual commanders were free to act within the intent of their superiors. In other words, orders typically stated desired goals and objectives instead of instructions on how to accomplish desired goals. Commanders were required to be familiar with the intent of their superiors two places above their own position in the hierarchy. One of the most important aspects of this philosophy was first-hand observation of the combat situation, allowing commanders to assume control of lower units at decisive points in the battle. Forward command required reliable, mobile communication, and tremendous

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[62]Bryan Perrett, *A History of Blitzkrieg* (London: Robert Hale, 1983), pp. 73-74.

[63]David P. Cavaleri, "British Tradition vs. German Innovation: The Continued Development of Mechanized Doctrine During the Interwar Years," *Armor* (March-April 1997): 10. pp. 8-11.

[64]Corum, *Roots of Blitzkrieg*, p. 108.; Perrett, *History of Blitzkrieg*, p. 67.

faith in available radio equipment. Field commanders like Erwin Rommel used this technique to great advantage, using their wireless-equipped command vehicles and unit signal establishments to maintain constant control at the precise echelon necessary.[65]

Guderian reaffirmed these ideas in his 1937 work on armored warfare, *Achtung Panzer!* While summarizing the *Wehrmacht*'s combined arms doctrine, he took time to outline the basics of German signal and command philosophy. Revealing the intent for primary reliance on radio-telephony, he stated, "Tank forces are directed by radio, and the smaller units from company downwards also by visual signals."[66] Signal flags, pyrotechnics, and smoke were necessary at the lower organizational levels because the individual tanks of a tank platoon were only equipped with receivers. Tank commanders, however, would possess transmitters as well as receivers according to the arrangement indicated by Guderian: "commanders ride in command tanks, which are followed by the necessary radio tanks for communication with superiors and subordinates."[67] Commanders were to ride in "armored radio vehicles with full cross-country capability," and "will be right up front with their tanks."[68] Combat communication would be facilitated by abbreviated voice procedure and pre-arranged signals. Additionally, radio was seen early on as the principal means of communication for the army as a whole. "Radio is likewise the principal medium of control between tank units and the other forces, and radios are the main equipment of the signals elements which provide the communications for the tank units and their supporting arms."[69]

By the time Hitler came to power in 1933, the *Reichswehr* had developed a complete complement of short-wave radio equipment to facilitate the conceived role of its

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[65]John F. Antal, "Forward Command: The Wehrmacht's Approach to Command and Control in World War II," *Armor* (November-December 1991): 26. pp. 26-29.

[66]Heinz Guderian, *Achtung Panzer!* trans. Christopher Duffy (Arms and Armor Press, 1992; 1937) p. 181.

[67]Ibid., p. 197.

[68]Ibid., p. 198.

[69]Ibid., p. 197.

armed forces.[70] Among the more important pieces of equipment was the 100 W.S., typically used by the various field headquarters, which could transmit either voice or telegraph requiring 25 Watts and 100 Watts respectively. Its maximum range with the aid of a 33 foot antenna was 45 miles for voice, and 125 miles for telegraph. The 100 W.S. was fairly durable, needing only three vacuum tubes, and could function as a stationary installation, or as a truck set. Also available was a series of transmitters for tank intercommunication. The 10 W.S.c (10 watt transmitter, model c) and the 10 W.S.h were used with the short-wave receivers Ukw. E. e and Ukw. E. h. The transmitters both issued amplitude modulated, high-frequency signals, each model a different frequency band, and could only transmit tone or voice. Range for voice communication was 3 miles stationary, and only 1.5 miles in motion. The receivers were of the seven-tube superheterodyne type, and could only receive the operating band of their corresponding transmitter.[71]

These items served with the *Wehrmacht* for practically the entire war, indicating both their usefulness, and the difficulty in upgrading a radio system in the midst of conflict. The Signal Branch, organized into well-integrated mobile units, operated this equipment. Each Army had its own Army Signal Regiment, as well as a Corps Signal Battalion for each corps, and a Signal Battalion for each division. Signal Battalions contained a Signal Company, which served the support function for the unit, a Telephone Company, and a Radio Company. Only the army-level Field Signal Commands were static units. They were deployed in hostile territory as permanent headquarters for the area signal installations.[72] The other signal units formed organic components of the units they supported, and were equipped to move with them.

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[70]Corum, *Roots of Blitzkrieg,* p. 108.

[71]Charles J. Berger, *Communications Equipment of the German Army 1933-1945* (Boulder, CO: Paladin Press, 1989), pp. 89-90, 139-140, 143.

[72]W. Victor Madej, *German Army Order of Battle, 1939-1945*, vol. 1 (Allentown, PA: Game Marketing Co., 1981), p. 113.

Skillful German commanders relied heavily on their signal service and armored communications vehicles. Rommel proved particularly adept at using radio to exert decisive personal influence over the battlefield both in France during 1940 and later in North Africa against the British. His success in the face of frequently poor odds indicated the force multiplication possible when an armored force is directed in real time through an effective radio-based communication system. While not employing the best equipment of World War II combatants, the German communication system represents a model because it mated an operational scheme that was attuned to the communications needs of the armored doctrine, with widely distributed, reasonably effective equipment. The German communication scheme allowed the fluid exercise of command and enhanced the Wehrmacht's tactical mobility because it was inherently flexible.

Chapter II

GREAT BRITAIN

The Interwar Situation

The British Army's attitude toward radio technology during World War I seemed progressive. Indeed, in the air, the "voice commanded squadron" had been a reality since August 1917, and on the ground, tacticians imagined applications that technology simply could not satisfy.[1] Britain retained its traditional disdain for land warfare, however, and while the Army enjoyed status unprecedented in British military history, it still took a back seat to the Admiralty and the fledgling Air Force for technological appropriations. A combination of influences during the interwar period generally tended to exaggerate this effect. While a great deal of overlap and interaction exists among them, four major factors affected the Army's employment of radio. Once identified, they will be applied to the Army's actual progress in radio use to demonstrate the exact nature of their impact. The first of these was the economic situation. The public attitude toward armaments, the Army, and the prospect of another Continental blood bath was a second factor. The popular fear of aerial terror bombing, and the Royal Air Force's exploitation of that fear to its advantage was a third, and the military's attitude toward mobile armored warfare the fourth.

The economic situation during the interwar years was hardly constant, but in general it was a difficult time for Britain. While it had not been a nation fond of a large standing army since Cromwell, before World War I Britain's resources were sufficient to raise a force capable of dealing with any foreseeable contingency. After the war, simply

[1]"Wireless Development During the War," p. 438.

defending the Empire was only nominally possible since newly acquired territory raised commitments without a corresponding increase in power. Maintaining the Empire was not a fixed cost, but whatever it demanded was non-negotiable for the British. Therefore, contingencies such as the problems with Ireland from 1919 through 1921, Shanghai in 1927, and in Palestine in 1929 and 1936 simply drained resources from other Army needs.[2] Primarily due to the needs of Imperial Defence, the Cabinet Finance Committee adopted the Ten Years' Rule in August 1919, under which Britain would expect no major war for ten years. Although originally adopted as an informal budgeting guideline, it became policy, and in 1928 Winston Churchill, then the Chancellor of the Exchequer, placed it on a rolling basis. The Ten Years' Rule was to roll until 1932.[3] By that time, the Great Depression, or Great Slump as the British knew it, had arrived, and further curtailed military spending until Hitler's threat became too ominous to ignore in 1936.[4]

Living under financial stringency does not preclude spending altogether, but it does require careful prioritization to secure those goods and services deemed essential. After their experience in World War I, the British people had no desire ever to fight another land war on the Continent, and consequently, developing that future capability simply was not a priority. The immense prestige the Army enjoyed during the war faded quickly as its generals became popular villains, their lack of imagination and incompetence perceived as the sole cause of the tremendous wartime casualties.[5] The public saw the accumulation of armaments as a major cause of the war, and so appropriations for and experiments with new weapons were relatively unpopular.

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[2]Brian Bond, *British Military Policy between the Two World Wars* (New York: Oxford UP, 1980), pp. 10, 18, 87, 89.

[3]Gustav Schmidt, *The Politics and Economics of Appeasement: British Foreign Policy in the 1930's,* Translated by Jackie Bennet-Ruete (Leamington Spa, UK: Berg Publishers, 1986), pp. 226, 253.

[4]Great Britain, Parliament, House of Commons, *Statement Relating to Defence, 3 March 1936*, Cmd. 5107, p. 847.

[5]Correlli Barnett, *Britain and Her Army, 1509-1970: A Military, Political, and Social Survey* (New York: William Morrow & Co., 1970), p. 412.

Popular acceptance and extension of the Ten Years' Rule, and hostility toward Army maneuvers in the military training areas being evidence to this effect. By 1929, the serious public call for disarmament forced the ouster of the Conservative government in favor of James Ramsay MacDonald's Labour Government; pacifism had emerged as a genuine political force.[6] Acutely conscious of this, the British government engaged in serious disarmament talks at the Geneva Disarmament Conference, which met from 1932 to 1934. The goal was an international agreement to reduce all armaments to the lowest possible levels of national security. Primarily, however, the British sought air disarmament. For the first time in history, the Home Islands were vulnerable to attack, and the relative inexpensiveness of air forces multiplied the potential enemies.[7] The overwhelming popular fear became the hypothetical surprise "knock-out blow" by some foreign air force.[8]

When the British finally began to contemplate rearmament in 1934, a Continental Expeditionary Force was an option, but the Government clearly considered it a low priority.[9] The Army's ability to field such a force received a crippling blow after Neville Chamberlain gained control of the government in May 1937. His Cabinet's monetary pressure on Secretary of State for War, Leslie Hore-Belisha, and his adviser, Basil H. Liddell Hart, caused them to recommend the abandonment of the Expeditionary Force based on the impossibility of fielding it in time to make a strategic difference.[10] After rearmament actually began, Army expenditures increased from £ 63,120,000 in 1937 to £

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[6]Uri Bialer, *The Shadow of the Bomber: The Fear of Air Attack and British Politics, 1932-1939* (London: Royal Historical Society, 1980), p. 9.

[7]C. J. Mackay, The Influence in the Future of Aircraft upon Problems of Imperial Defence," *Royal United Service Institution Journal* (May 1922): 283, 286.

[8]Bialer, *The Shadow of the Bomber,* p. 11.

[9]*Statement Relating to Defence, 3 March 1936*, p. 847.

[10]Bond, *British Military Policy,* p. 276.; Basil H. Liddell Hart, "The Defence of Empire," *Fortnightly Review* (January-June 1938): 27.

148,155,000 in 1939, primarily to enhance anti-aircraft defense capability.[11] The Expeditionary Force finally received funds in this last year, when Chamberlain belatedly decided to send a full thirty-two division army to France.[12]

When the decision to rearm came, the RAF, not the Continental Expeditionary Force, found itself at the top of the priority list. Immediately after the war, this would not have seemed like the likely result. The world's first independent air service, formed in April 1918, came under immense pressure from the Army and Navy to disband and be reincorporated as dependent air arms. Its leader, Air Chief Marshall Sir Hugh Trenchard, devoted his efforts to the survival of his charge. Though not initially a proponent of strategic-bombing doctrine, Trenchard realized that a strategic capability was the only justifiable reason to remain independent. Considering the financial situation caused by the Ten Years' Rule and contemporary technological capabilities, developing a blatantly offensive role would have been politically impossible. Along with advocating its strategic role, the RAF correspondingly felt compelled to de-emphasize air-to-ground cooperation.[13] In fact, until 1939 the RAF officially considered the close tactical cooperation with armored forces a relic of trench warfare.[14] To remain independent, the RAF would have to avoid commitments that might jeopardize its ability to accomplish its preferred role. Committing its limited resources to large-scale tactical cooperation, and risking subordination to ground commanders was out of the question. Consequently, the only Army cooperation the Royal Air Force gave priority was artillery observation and

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[11]Great Britain, Parliament, House of Commons, *Memorandum by the Secretary of State for Air Relating to the Air Estimates for 1939,* Cmd. 5953, p. 309.; Great Britain, Parliament, House of Commons, *Army Estimates for the Year Ending 31 March 1939*, p. 535.

[12]Michael Howard, "British Military Preparations," in *British Appeasement and the Origins of World War II*, ed. R. J. Q. Adams (Lexington, MA: D. C. Heath and Co., 1994), p. 59.

[13]E. L. Gossage, "Air Cooperation with the Army," *Royal United Services Institution Journal* (1927): 571.; T. L. Leigh-Mallory, Wing Commander, "Air Cooperation with Mechanized Forces," *Royal United Services Institution Journal* (1930): 566.; M. Everett, Colonel, "Fire Support from the Air," *Royal United Services Institution Journal* (1938): 587.

[14]Gossage, "Air Cooperation with the Army," p. 571.; A. J. Capel, Group Captain, "Air Cooperation with the Army," *Royal United Services Institution Journal* (1939): 283.

reconnaissance.[15] The resulting policy was one of Imperial policing and home defense, and was so effectively advocated that in 1923 Parliament ignored the Ten Years' Rule, and approved the construction of the Home Defence Force.[16]

The Home Defence Force was to consist of 52 fighter and bomber squadrons with accompanying manning, training and basing requirements, and was scheduled for completion in 1928.[17] As a result, between 1922 and 1929, while Army expenditure fell by £ 21,755,000, RAF spending actually increased from £ 15,660,000 in 1922 to £ 21,319,000 in 1925 before dropping back to £ 16,200,000 in 1929.[18] In spite of this tremendous victory on paper, unanticipated problems with land purchase, training and developing aircraft put the Home Defence Force two years behind schedule by 1926.[19] Additionally, as is apparent from the actual expenditures, financial considerations also began to tell on the RAF by 1926. Although expansion continued until the Depression, by Trenchard's retirement in 1929, the Home Defence Force contained only 28 squadrons.[20] These frustrations caused the RAF to publicize the air threat that it alone would be capable of preventing. Throughout the Geneva Disarmament Conference, aerial disarmament was primary in the eyes of the public, at least partially a result of RAF

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[15]Everett, "Fire Support from the Air," p. 587.

[16]Scot Robertson, *The Development of RAF Strategic Bombing Doctrine, 1919-1939* (Westport, CT: Praeger Publishers, 1995), pp. 16, 26, 37.

[17]Great Britain, Parliament, House of Commons, *Memorandum by the Secretary of State for Air Relating to the Air Estimates for 1923-1924*, Cmd. 1826, p. 758.; Great Britain, Parliament, House of Commons, *Memorandum by the Secretary of State for Air Relating to the Air Estimates for 1932*, Cmd. 4026, p. 226.

[18]Great Britain, Parliament, House of Commons, *Memorandum by the Secretary of State for Air Relating to the Air Estimates for 1925*, Cmd. 2070, p. 798.; Great Britain, Parliament, House of Commons, *Memorandum by the Secretary of State for Air Relating to the Air Estimates for 1929*, Cmd. 3274, p. 259., Great Britain, Parliament, House of Commons, *Army Estimates for the Year Ending 31 March 1930*, p. 383., Great Britain, Parliament, House of Commons, *Memorandum by the Secretary of State for War Relating to the Army Estimates for 1927*, Cmd. 2810, p. 2.

[19]Great Britain, Parliament, House of Commons, *Memorandum by the Secretary of State for Air Relating to the Air Estimates for 1926*, Cmd. 2589, p. 3.

[20]Great Britain, Parliament, House of Commons, *Memorandum by the Secretary of State for Air Relating to the Air Estimates for 1927*, Cmd. 2814, p. 3.; Great Britain, Parliament, House of Commons, *Memorandum by the Secretary of State for Air Relating to the Air Estimates for 1929*, p. 259.

propaganda.[21] Consequently, when the British finally discarded the peaceful solution, the air threat demanded the most military attention. Government spending reflects this priority, as spending on the RAF for 1937, 1938, and 1939 reached £82,500,000, £ 125,621,000, and £205,951,000 respectively.

In the midst of this almost universal and official disdain for the Army, its leadership was seriously divided as to the proper course it should take, and many of its officers were, as Brian Bond describes it, "so far from wishing to adapt to social and technological changes" that they "looked to the army as a haven where they could escape from them."[22] The tremendous task of digesting the war's lessons placed Army members into two camps, one wishing to return the Army to its comfortable prewar configuration and mindsets, and the other wishing to address the changes accompanying technological advancements. The first group had the weight of tradition and the influence of the often recalcitrant senior leadership. The powerful commanders of the older branches campaigned to insure that the Infantry and Cavalry retained their traditional roles, and did not suffer loss of funding to mechanization. The second group had the compelling argument that technology had forever changed warfare. Could Infantry ever advance unprotected against machine guns? Could horse cavalry defeat a faster, better armed, and more protected mechanized force? With the exception of General George F. Milne, a professed armor enthusiast who served as Chief of the Imperial General Staff (CIGS) from 1926-1933, most of those pushing for armor development were younger and correspondingly less influential. Britain's famous armor advocates, J. F. C. Fuller and Liddell Hart were widely heard, but largely unable to capture public and organizational imagination.

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[21]Bialer, *The Shadow of the Bomber,* p. 11.
[22]Bond, *British Military Policy*, p. 35.

These influences culminated in Chamberlain's Appeasement policy of 1937 through 1939. Economic and popular forces pushed Britain away from developing a force capable of intervention on the Continent, and fear of a terror attack from the air moved the Royal Air Force to the forefront. External forces were thus hostile to the development of a workable mobile armored warfare doctrine based on the effective use of radio communication. Internally, the British Army possessed a few progressive officers, but the overall trend, especially as time passed, was one of mental stagnation.[23] This framework shaped and confined the British Army's attempts to adapt radio communication to armored warfare.

Radio in the Immediate Post-War Years, 1919-1924

This early period begins with the close of the Great War and ends with the British Army's initial deployment of its first complete wireless communication system. The military was largely in a state of confusion, and the overriding concerns were disarmament and securing a treaty agreement with the defeated Central Powers. Almost immediately, the Ten Years' Rule went into effect, and while the government did not plan to field a military force for war purposes, military chiefs were naturally expected to prepare, at least on paper, for that eventuality. The process of interpreting the war's lessons and preparing for future conflict was just underway.

The proponents of airpower got an early start, and articles in daily newspapers like the *Times* began to appear with some frequency. A January 1920 article called for public mobilization to force the government to encourage air power progress. Citing "an almost complete lack of interest on the part of the man on the street in the impending development of aerial power," the writer warned that air power would enable "sudden and crushing" attacks forcing the victim to "surrender practically before it can deliver a

[23]Barnett, *Britain and Her Army,* p. 412.

blow."[24] Winston Churchill, as Secretary of State for Air, pushed the development of air power early on, proposing generous estimates for the RAF, that, at least in 1921, were still too generous for public approval.[25] While the government still felt it desirable to reduce spending on the RAF, cutting its budget twenty percent between 1921 and 1922, public discussion of aerial attack was intensifying.[26] Articles by RAF generals appeared warning of the nation's inability to deal with the impending disaster from the air.

One General Groves warned of this possibility, and added that the nation in possession of "aerial supremacy" could prevent such attacks, and could even prevent the mobilization of potential enemies, thus presumably eliminating conventional war.[27] Similar articles continued to appear, usually editorials or contributions from the aeronautical correspondent, culminating in the early August announcement by the government that it would add 500 aircraft for home defense.[28] Besides deflecting public outcry, the decision was also directed at rescuing the aircraft industry, which was near collapse from inactivity.[29] In June of 1923, Sir Samuel Hoare, the new Secretary of State for Air, announced the establishment of the 52-squadron Home Defence Force, slated for completion in 1928. By 27 July 1923, a unit of RAF bombers, and two Territorial anti-aircraft batteries had carried out an exercise to explore some of the problems associated with protecting London from air attack. Clearly, the air menace had rooted itself in the minds of the RAF leaders, the government, and the public at large.

Those who advocated developing tank technology did not achieve results as quickly as the air power enthusiasts. In the Secretary of State for War's memorandum on

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[24]"Foundations of Air Power," *Times* (London), 19 January 1920.

[25]"Help for our Air Rivals," *Times* (London), 3 March 1921.

[26]Great Britain, Parliament, House of Commons, *Memorandum by the Secretary of State for Air Relating to the Air Estimates for 1922*, Cmd. 1607, p. 683.

[27]"Aircraft Policy," *Times* (London), 1 April 1922.

[28]"Air Attack," *Times* (London), 15 April 1922.; "Air Power," *Times* (London), 3 May 1922.; "Future of Air Power," *Times* (London), 8 August 1922.; "New Air-Power Policy," *Times* (London), 9 August 1922.

[29]*Times* (London), 9 August 1922.

the Army Estimates of 1920, Churchill clearly established that Imperial Defense would receive first priority, and would be governed by pre-war principles. Of secondary importance was the need to experiment with new methods of warfare. Since the conflict ended successfully for Britain, there was little incentive to alter contemporary theories of warfare. Attrition, or the systematic and deliberate destruction of the enemy's manpower and resources, dominated strategic thinking during the Great War. Churchill reaffirmed this idea in his memorandum.[30] In attrition warfare, the tank's role was necessarily tied to the infantry, since the clash of infantries was seen as the decisive action in attrition warfare.

J. F. C. Fuller emerged as the foremost advocate for tank development. During the War, Fuller had been the leading tank strategist, planning the Battle of Cambrai, and forming Plan 1919, which the Allies were to execute against the Germans in that year. Though never implemented, it outlined the basic tank employment concepts the Germans employed in their World War II *Blitzkrieg* tactics. While fulfilling his duties at the War Office, Fuller began to publish articles in military journals advocating the development of the tank arm. Fuller saw future warfare as radically different from what came before. Technological advances in the form of tanks, aircraft, and radio would make it possible for a "Tank Battalion commander to accompany his machines by aeroplane into battle and to issue to his subordinates his verbal orders."[31] It would take another tank advocate, however, to complete the break with traditional Army thinking. Liddell Hart, though not a tank man in the war, was converted by Fuller, and soon began publishing his own articles on the subject. Liddell Hart's principal contribution was the recognition that the aim of warfare was not to destroy the enemy army, but to destroy the enemy's will to

[30]Great Britain, Parliament, House of Commons, *Memorandum by the Secretary of State for War Relating to the Army Estimates for 1920*, Cmd. 565, pp. 161, 163.

[31]J. F. C. Fuller, "The Application of Recent Developments in Mechanics and other Scientific Knowledge to Preparation and Training for Future War on Land," *Royal United Services Institution Journal* (May 1920): 246.

continue the war.[32] Separating victory from the strategy of attrition was essential to the acceptance of fluid, mobile tank warfare, and essential to divorce Army thinking from the Great War's linear infantry advances.

The tank's postwar existence was in doubt, for even though Churchill claimed the intention to build a new tank model, he had also decided not to create a separate Tank Corps.[33] Through Fuller and Liddell Hart's efforts, the Army officially announced in 1921 that work was to begin on a new tank, the Vickers Mk II.[34] The fifteen ton Vickers, which could travel ten miles per hour cross-country, carried four men (five if equipped with a wireless set).[35] This tank made its entrance at Aldershot training ground with the newly formed Royal Tank Corps in 1923, and remained the staple of the Tank Corps until 1937.[36] The tank as a tool of war was finally on firm footing in the British Army. The 1923 Aldershot exercise also had relevance for using wireless communication with tanks. Although it was "not entirely possible to rely on wireless for the signal communication of the army," experiments indicated that using wireless to communicate between tanks and aircraft on the move was "very promising."[37] The Army held exercises again the following year, and displayed a few units of Vickers tanks. Lecturing on the subject at the Royal United Services Institution on 19 November 1924, Fuller asserted that the 1924 Exercises demonstrated that mobility would be the key to the next war. He based this conclusion on the success of a Vickers unit possessing a tank fitted with an "extemporized radio-telephone" for communication with headquarters. The radio-equipped unit was allowed to operate independently of the infantry, and enjoyed some

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[32]Larson, *The British Army and the Theory of Armoured Warfare,* p. 85.

[33]*Memorandum by the Secretary of State for War Relating to the Army Estimates for 1920*, p. 163.

[34]"Improving the Tank," *Times* (London), 4 August 1921.

[35]Peter Chamberlain and Chris Ellis, *British and American Tanks of World War II: The complete illustrated history of British, American and Commonwealth tanks, gun motor carriages and special purpose vehicles, 1939-1945*, 2d ed. (New York: Arco Publishing Co., 1975), p. 29.

[36]Larson, *The British Army and the Theory of Armoured Warfare,* p. 123.

[37]Great Britain, Parliament, House of Commons, *Memorandum by the Secretary of State for War Relating to the Army Estimates for 1924,* Cmd. 2061, p. 321.

success. To Fuller's displeasure, however, other tank units remained tied to the infantry in the traditional close support role.[38]

These experiments with radio are partially an outgrowth of an early interest that military and civilian organizations alike displayed for radio technology. For its part, the Army established the Royal Corps of Signals in 1920. Citing the important part played by communications and signals in the war, it mandated that the "Army should be thoroughly conversant with progress in wireless telegraphy, and capable of adapting any new developments to its particular needs."[39] Most of the money outlayed for the Signal Corps that year was dedicated to developing Field Wireless Stations. Also in 1920, the British government established the Radio Research Board (although it did lag by a year the establishment of the Chocolate, Cocoa, Sugar Confectionery and Jam Manufacturer's Research Association).[40] The Radio Research Board was to coordinate the independent radio research efforts of the War Office, Admiralty, Air Ministry, and Post Office, with the purpose of preventing overlap and facilitating combined efforts.

The Board identified four major problems: the "propagation of waves," "atmospherics," "directional wireless," and "thermionic valve physics." The first included issues like the attenuation of transmitted waves, and the relationship between power and range for waves of various frequencies. Atmospherics was the study of the interfering effects of magnetic properties of the atmosphere, which differed with night and day, and with weather phenomena. Directional wireless was primarily a concern of the RAF and the Navy, as it had profound navigational implications. Finally, the thermionic valve research comprised the largest effort. This was a device similar in

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[38]J. F. C. Fuller, "Progress in the Mechanization of Modern Armies," *Royal United Services Institution Journal* (1925): 78.

[39]*Memorandum by the Secretary of State for War Relating to the Army Estimates for 1920*, p. 163.

[40]Great Britain, Parliament, House of Commons, Department of Scientific and Industrial Research, *Annual Report, 1918-1919*, p. 728.; Great Britain, Parliament, House of Commons, Department of Scientific and Industrial Research, *Annual Report of the Board, 1920*, p. 187.

principle to the audion, only it functioned in the open air without a vacuum tube. Its application, once made practical, could reduce the size and weight while increasing resilience of wireless sets.[41] These endeavors would occupy the Radio Research Board for most of the interwar period.

In 1922, the Radio Research Board Subcommittee on Radio Telegraphy conducted a study of military and civilian radiotelephone applications. Composed of representatives from each branch of the military and the Post Office, the subcommittee concluded that "for transmission of a specific message over any distance--long or short--the radio-telephone is greatly inferior to the radiotelegraph in accuracy, speed, and cost, and is likely to remain so."[42] Other reasons for this conclusion were the necessity of repeating unusual words, and the need for skilled operators similar to those required for W/T. The subcommittee went on to warn of mutual interference when multiple sets were operated in a small area, and declared that radiotelephone should only be used when all other methods were impractical. In a lone bright spot, it did identify radio's utility for communication over "very short distances, when personal communication between principals is essential and secrecy is unimportant," an applicable insight to the control of a mobile armored force.[43] The subcommittee reached these conclusions based on 1922 radiotelephone technology, which used wavelengths between 200 and 300 meters.

A technological improvement emerging the following year presented a solution some of the radiotelephone's problems. The wartime invention of the high-frequency vacuum tube transmitter and Armstrong's superheterodyne receiver made it practical to utilize previously inaccessible frequencies. Always the opportunist, in 1923 Marconi carried out a number of experiments with short-wave transmitters and receivers,

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[41] *Annual Report, 1920*, Department of Scientific and Industrial Research, p. 187.

[42] Great Britain, Parliament, House of Commons, Radio Research Board, Subcommittee on Radio-Telegraphy, *Report, 1922*, p. 581.

[43] Ibid.

employing wavelengths of less than 100 meters, which everyone else in the field had practically ignored. He sailed the floating laboratory on his yacht toward the Cape Verde Islands, recording differences in signal strength the entire way, and assembling the first data on long distance short-wave communication. The results were so promising that Marconi redoubled his efforts, and by 1924 had revitalized the field of wireless communication.[44]

The short-wave radio, he discovered, possessed several advantages over those employing longer waves. Lower power requirements allowed significant weight and space savings through smaller batteries. Short-wave signals carried more information per second by virtue of their higher frequency, enhancing encryption capabilities for wireless telegraphy. They were also more resistant to atmospheric and vehicular interference, and several more frequencies were available, reducing the mutual interference associated with the operation of multiple sets in a small area. As tank radio designers would later discover, the short-wave also required a much smaller aerial. The only real disadvantage was an increased tendency for the signal to fade over long distances.[45] By 1925, the National Physical Laboratory had developed a highly capable short-wave apparatus capable of transmitting with a mere 15 watts of power.[46] Short-wave radio promised to address some of the difficulties with mobile wireless; but at this point, information was still transmitted as amplitude modulated waves.

The difficulty with AM was that static electricity generated by tank tracks, and sparks from the engine's spark plugs interfered with the amplitude of the incoming waves. These sparks, just like those from Hertz's spark gap transmitter, emitted their own electromagnetic waves that mingled with the intended radio signal. Because intended

[44]Baker, *A History of the Marconi Company,* pp. 219-220.

[45] Chetwode Crawley, "Wireless Telegraph Communication," *Electrical Review* 100 (13 May 1927): 749-750.

[46]Great Britain, Parliament, House of Commons, Department of Scientific and Industrial Research, *Annual Report of the Board, 1926*, pp. 783-784.

amplitude modulations and those introduced by the tank itself were indistinguishable to radio receivers, no amount of filtering could remove the unwanted noise without also removing the intended signal, making often overwhelming static a fact of life while the engine was running, and communication while in motion very difficult. By increasing transmission power, the signal to noise ratio could be increased, making a modest amount of filtration possible.[47] Physical measures were also taken, including electronically shielding the spark plugs, and electrically bonding the tank treads, but the results were far from perfect. The solution would not emerge until 1933, when Edwin Armstrong developed frequency modulation. Principally for economic reasons, the British never embraced frequency modulation, and only used it modestly in World War II.[48] For the British Army, the technical foundation for its wartime radio communications had been established by 1923.

The Temporary Reign of Mobile Doctrine, 1925-1928

Unfortunately for Britain, the short-wave radio emerged a year after Parliament began appropriating funds to supply the British Army with wireless sets using longer wavelengths.[49] These sets were the work of the Marconi Wireless Telegraph Company, and were ready for purchase in February 1924.[50] The Army ordered three different sets, the MA, the MB, and the MC, which they procured from 1925 to 1928. However, the Expeditionary Force did not receive them in significant numbers until 1928.[51] The MA

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[47]John F. Rider, FM: An Introduction to Frequency Modulation, New York: John F. Rider Publisher, 1940, pp. 2-3.

[48]Gravely, T. B., ed. *The Second World War, 1939-1945, Army: Signal Communications.* (Great Britain: The War Office, 1950), p. 174.

[49] Great Britain, Parliament, House of Commons, *Manufacturing Accounts of the Army Ordinance Factories,* 1925, p. 867., 1925, p. 27., 1927, p. 27., 1928.

[50]"An Infantry Radio Outfit," *The Electrical Review,* 8 February 1924 p. 236.

[51]*Manufacturing Accounts of the Army Ordinance Factories*, 1925-1928. The majority of the outlay for these sets was in 1925 and 1926, where a total of £55,122 was appropriated. An additional total of £19,650 was spent in 1927 and 1928., Bond, *British Military Policy,* p. 145.

was housed in a lorry, and was employed by regimental headquarters, and by individual units as a link to the rear. The MB was installed in armored cars and Vickers tanks, and was also carried by the infantry. The MC set was placed in light tanks.[52] Marconi's sets were an improvement over the radiotelephones discussed by the subcommittee, but they still employed the longer wavelengths. The MB operated on wavelengths between 190 and 260 meters, employed a vacuum valve, and was capable of both telephony and telegraphy. Intended for infantry, the set weighed a total of 157 pounds divided into four roughly equal loads. There were two aerials, one placed on two five-foot masts, and one supported by a thirty-foot mast for extended range. Telegraph range was about three miles, and, due to a buzzer modulated, or tone, transmitter, up to 16 different sets could operate in that three-mile radius without serious interference.[53] The range of effective telephone communication was similar, but the level of mutual interference was still not completely satisfactory.

The year 1925 also marked the first Army-level maneuvers since the pre-war work of 1913. The Army had held, as mentioned, a number of minor exercises, the notable ones being those of 1923 and 1924. To prepare for the Manoeuvers, the Army held an exercise in late May to test the entire gamut of signaling apparatus, including dispatch riders on motorcycles and bicycles, line telegraphy and telephony, visual signaling, and both varieties of wireless communication. In most respects, the practice was to constitute the last word on the Army's battlefield communication organizational concept. Except for the link between the Corps and the three Divisions, which did not employ dispatchers, a triple-redundant combination of line, wireless, and dispatch riders connected the various headquarters. Cooperating RAF units communicated with the Corps headquarters by radiotelephone, but front-line communications overwhelmingly

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[52]Woods, *Tactical Communication Techniques,* p. 230.

[53]Tone telegraphy increased the number of sets that could operate on the same frequency by allowing several sets to transmit on a distinguishable tone. "An Infantry Radio Outfit," pp. 236-237.

relied on visual signals. In the advance, the idea was to move forward line and wireless communication from strategically located "signal centers." If the advance continued, the signal centers themselves would be moved forward, and the cycle would begin again.[54] This exercise emphasized the linear nature of Army communication doctrine, as well as the role of wireless within that doctrine. Wireless was relegated to a supporting role for the preferred line telephone. At this point the radiotelephone simply was not available in large enough numbers to serve as an independent source of information, and because they used long-wave, amplitude modulated transmitters, the existing sets were difficult to operate. Unfortunately, even though superior radio technology existed, the radiotelephone's secondary role persisted in the minds of Army leadership for the remainder of the interwar period.

The stated purpose of the 1925 Army Manoeuvers was four-fold. The Army was to practice handling large formations, test its communication services, experiment with mechanized units, and practice cooperation with the RAF.[55] The Manoeuvers enjoyed mixed success. From the official Army perspective, accounts were positive. Specifically, assessments were highly favorable of the new wireless system, and prospects favored the formation of a mobile, combined arms unit for experimentation. On wireless, the Secretary of State for War, Laming Worthington-Evans, found the new sets "well-adapted to use in the field," and that they had led to "instructive experiments in the use of this form of communication between aeroplanes and tanks." Finally, grossly overstating the contemporary capabilities, he declared: "The wireless system may now be said to have taken its place alongside the field cable as a principal means of telegraphic communication in the Army."[56] Acknowledging the Tank Corps' limited success,

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[54]"Army Training," *Times* (London), 27 May 1925.

[55]Great Britain, Parliament, House of Commons, *Memorandum by the Secretary of State for War Relating to the Army Estimates for 1926*, Cmd. 2598, p. 5.

[56]*Memorandum by the Secretary of State for War Relating to the Army Estimates for 1924-1925*, Cmd. 2359, p. 607.

Worthington-Evans also stated the intention of fielding a "small mechanical force of all arms." Unfortunately, he saw Britain's lead in mechanization as a cushion, and seeking comfort rather than innovation, was in no rush to develop this capability.[57]

Unlike the Secretary of State, the Manoeuvers displeased Liddell Hart, who identified the main lessons from the maneuvers as the need to learn from mistakes, the effects of the "friction of war," and the difficulties of transitional periods. Liddell Hart's main objection was the misinterpretation of mobile warfare, as evidenced by the incident with the "mobile" infantry being deposited 10 miles from the front, and the Tank Corps largely watching from the sidelines. When employed, the Tank Corps often arrived at its objectives dissipated and disorganized. Tank commanders exercised poor control of their units, and because of inadequate reconnaissance, were usually unaware of their enemies' location. Their problems were largely a result of inadequate information flow, caused by a lack, or misuse, of wireless. He concluded with a call for advancement in communication and tank technology.[58]

Another lesson that emerged from the Manoeuvers was the need to develop tactical air power, specifically close-support work with ground forces. Lt. Col. F. A. Pile of the Royal Tank Corps acknowledged the RAF's work on air reconnaissance and artillery spotting, but cited the need for a "low-flying attack squadron" to assist the advance of tank units. At that time not even a serious effort to practice such air-ground cooperation occurred.[59]

The glaring lack of a workable mobile doctrine, and the promise of tank formations and aircraft linked by radiotelephone, were the best results of the 1925 Manoeuvers. Because of these realities, the Army came as close as it would ever get to

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[57]Ibid.

[58]B. H. Liddell Hart "Army Manouvers, 1925," Royal United Services Institution *Journal* (1925): 655.

[59]F. A. Pile, "The Army's Air Needs," *Royal United Services Institution Journal* (1926): 726-727.

developing a workable mobile armored doctrine in 1926. Toward the end of 1925, General George Milne was nominated as Chief of the Imperial General Staff. He was, as mentioned, a believer in mobile armored doctrine, and as a signal of his intentions, named Fuller his Military Assistant. Between his nomination and acceptance of the position in February 1926, however, Milne grew cautious. According to Liddell Hart, his early announcements of wholesale change alarmed his more conservative associates, especially as he had formed his view of armored doctrine by reading the ideas of others instead of internal reflection. He therefore advocated a slow transition to mechanization, and discouraged some of the more progressive proposals that surfaced that year.

The most significant event of 1926 was the 13 November Tank and Motor Display before various members of the government, which involved almost all the new forms of mechanical transport, including an advanced heavy tank designed for employment in an independent mobile force. According to Liddell Hart, the display ended with a short combined arms exercise demonstrating all of the elements of *Blitzkrieg*, including independent tank operation, mobile artillery support, and tactical air support.[60] However, a *Times* correspondent made no mention of it, and cited a mobile bridging display as the day's last and most interesting demonstration. He also stated that the display made it clear that "sufficient research and experimental work had not been carried out to justify passing to the production stage excepting in a great war emergency," since "everything mechanized that was shown was either experimental or obsolete."[61] Despite these negative reports, the display impressed Army officials, who stepped up organization of the Experimental Armoured Force promised by Worthington-Evans.

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[60]B. H. Liddell Hart, *The Tanks: The History of the Royal Tank Regiment and its Predecessors Heavy Branch Machine-Gun Corps and Royal Tank Corps, 1914-1945*, vol. I. (New York: Frederick A. Praeger Publishers, 1959), pp. 241, 243.

[61]"The British Army To-Day," *Times* (London), 15 November 1926.

In December, Milne informed Fuller of his appointment to command the 7th Infantry Division at Aldershot. Even though he would be allowed access to the division's resources to conduct experimentation with a mobile force, Fuller was not satisfied with the arrangement, because any experimentation would have to take place in conjunction with infantry training. Not wishing to be distracted, nor willing to risk Infantry domination, Fuller refused the assignment. Even without the Army's foremost tank expert, Milne went ahead with the plan, and established the Experimental Armoured Force under Colonel R. J. Collins, who had been the Director of Military Training in India, and had experimented with mechanization, though he was not regarded as an adherent to any particular school of thought. In addition to an RAF Army Cooperation Squadron for reconnaissance and artillery work, and the occasional addition of fighter and bomber squadrons for close support, the force itself would consist of an armored car company, a Royal Artillery field brigade, an infantry brigade, and a Tank Battalion.[62] The Tank Battalion was organized into a headquarters and three companies, each company having three sections of five tanks.[63] Communication by radiotelephone was only thought necessary between the companies and battalion headquarters, so only four tanks were equipped with MB wireless sets.

This communication arrangement was applied to the entire Royal Tank Corps and remained in place; for apart from the initial wireless purchase and limited experimental purchases, the government made no provisions to increase the number of wireless sets issued to tank units, or to the Army as a whole until 1939.[64] Signaling doctrine in the Army during 1926 was largely similar to that revealed in the preparatory exercise of

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[62]"Mechanization in the Army," *Times* (London), 28 April 1927.

[63]B. H. Liddell Hart, *The Tanks*, p. 247.

[64]Great Britain, Parliament, House of Commons, *Army Estimates for the Year Ending 31 March 1927,* p. 38.; Great Britain, Parliament, House of Commons, *Manufacturing Accounts of the Army Ordinance Factories,* 1925, p. 867.; 1925, p. 27.; 1927, p. 27.; 1928.; 1929, p. 885.; 1930, p. 850.; 1931.; 1932.; 1933.; 1934, p. 839.; 1935, p. 897.; 1936, p. 965.

1925. Line communication was considered preferable when available, but the most effective system for rear areas was one of redundant line, wireless, and dispatch riders. Maintaining communication with forward troops would remain a problem until a radiotelephone was developed that could be easily carried, was robust, and had no visible aerial. Most important to this discussion, intercommunication between tanks was deemed necessary, but was impractical because placing radios in every tank would create a number of problems, including increased space demands within the tank, increased demands on the already overtaxed tank men, and the "chaotic mutual interference" that would result.[65] Short-wave technology would largely solve these problems, but for the time being, the Army made no plans to equip all tanks with radios. Worthington-Evans, in his memorandum on the Army Estimates of 1927 revealed the Army's priorities: "the provision of Engineer and Signal technical equipment has been rigidly curtailed, in view of the more important requirements for armaments and modernized vehicles."[66]

The signal resources for an average division in 1926, including a few wireless sets that had yet to be delivered, consisted of 10 wireless sets for headquarters, 4 for each infantry brigade, the 4 tank sets, and notably, none for artillery.[67] Although the Royal Tank Corps expressed the desire to have air cooperation with tank offensives in 1926, the only form acceptable to the RAF was reconnaissance and artillery observation. Here the Royal Air Force asserted control over air-to-ground communication by insisting that RAF liaisons be the sole contacts with pilots in the air.[68] Masked by the argument of pilot overload was the distaste among airmen for the thought of any direct Army control over

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[65]R. Chenevix French, "Signal Communications in War," *Royal United Services Institution Journal* (1927): 299, 306.

[66]Great Britain, Parliament, House of Commons, *Memorandum by the Secretary of State for War Relating to the Army Estimates for 1927*, Cmd. 2810, p. 9.

[67]French, "Signal Communications in War," p. 298. This article does contain a discrepancy on the number of tank wireless sets. It states the number is five, but Army Estimates consistently indicate only four.

[68]Capel, "Air Cooperation with the Army," p. 571.

air assets. With regard to aircraft-to-tank communication, RAF thinkers recognized the usefulness of radiotelephone, but complained of the problems with fading and location by enemy direction finders. Preferable to direct tank communication was communication with a Royal Tank Corps contact at division headquarters. In the future, if the Army ever deployed independent tank units, the RAF might consider direct communication.[69]

Unfortunately, most airmen regarded air cooperation with ground troops as an outdated, trench warfare concept. Royal Air Force operational priorities reflected the continuing need to emphasize their strategic role, since 1927 still found the RAF fighting the Treasury to meet the building quotas established for the Home Defence Force. Air Force roles outlined in 1927 placed Army and Navy cooperation last, behind commerce protection, Imperial policing, and its primary role: national defense through offensive operations against enemy nations.[70] Presumably, Germany was the prospective foe, although in 1927 France was the only other nation in Europe with a significant air force, and as late as 1925 the RAF was only capable of mounting 700 mile round trips, without a bomb load.[71]

Nevertheless, the Royal Air Force continued to contemplate tactical cooperation with land forces, as evidenced by the 1927 Army exercises, which represented the only time the Experimental Armoured Force operated under an unadulterated mobile doctrine in line with the thoughts of Fuller and Liddell Hart.[72] On 14 September, during the 4th Infantry Division training, a small armored force ended the exercise early with a decisive sweep around opposing infantry to attack from the rear. The *Times* correspondent reported that, "The moral [sic] which attaches to the intervention of a Mechanized Force

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[69] J. A. McDonald, "Communications between Army Formations and Aircraft in Mobile Warfare," *Royal United Services Institution Journal* (1927): 126.

[70] Capel, "Air Cooperation with the Army," p. 571.

[71] "Flight to Scotland and Back," *Times* (London), 29 October 1925, p. 16b

[72] "Army Training," *Times* (London), 17 September 1927.

is so obvious as scarcely to need discussion."[73] In a separate exercise on the 16th, the Experimental Armoured Force under Colonel Collins started 40 miles away from the 3rd Infantry Division, and was ordered to execute an indirect attack on its flank. After a swift closure, Collins' force smashed into the side of the 3rd, accompanied by strafing aircraft and artillery support.[74] Liddell Hart proclaimed the exercises as a whole "the turn of the mental tide in the progress toward mechanization."[75]

The exercises of 1927 were a triumph for the mobile armored warfare advocates but, ironically, that triumph ultimately proved detrimental to the adoption of such a doctrine. The continued emphasis on the Experimental Mechanized Force by Milne precipitated a reactionary movement by the traditional arms, which in turn caused the formerly progressive CIGS to vacillate on mechanization.[76] For the exercises of 1928, he announced that the first half would feature the Experimental Armoured Force independently, but in September, tank units would cooperate with the traditional arms. Meanwhile the Experimental Armoured Force enjoyed a brief place in the national spotlight. In May, June, and July it held demonstrations for the King, Members of Parliament, and other government officials, focusing primarily on overcoming obstacles in the field, firepower, cooperation with RAF squadrons, and keeping in touch with dispersed units through wireless.[77] Particularly interesting was the display that occurred on 12 July, during which the Secretary of State for War praised the Experimental Armoured Force. The correspondent reported, "the mere fact that something new was being done had put fresh life in the military forces in the army," and that even being attacked by tanks was "exhilarating and stimulating."[78]

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[73]"Army Training," *Times* (London), 15 September 1927.

[74]*Times* (London), 17 September 1927.

[75]B. H. Liddell Hart, "Army Training 1927: Conversion by Demonstration," *Royal United Services Institution Journal* (1927): 746.

[76]B. H. Liddell Hart, *The Tanks*, p. 255.

[77]"The Experimental Armoured Force," *Times* (London), 20 May 1928

[78]"The Armoured Force," *Times* (London), 13 July 1928.

For the Experimental Armoured Force, however, its last independent exercises were a vague replay of those of the year before, only with older tanks and fewer vehicles. Liddell Hart dismissed 1928 as "the year of making shift."[79] Nothing particularly interesting occurred regarding tank tactics: similar flanking attacks from the previous year were executed, and combined efforts with infantry essentially followed those established eleven years before.[80] While mundane in themselves, the 1928 Exercises were important for two reasons. First, tank performance in conjunction with the infantry was not decisive in itself, but commanders soon discovered that men became sluggish and demoralized outside the range of their anti-tank defenses so that infantry did not reach some of its objectives.[81] In November, Milne dissolved the Experimental Armoured Force ostensibly to make room for new experimentation, but in reality to improve the morale of cavalry and infantry formations and placate their advocates.[82] The development of armored doctrine would never command the same official beneficence nor would it occupy the minds of Army leaders as it had in 1927 and 1928.

The second lesson dealt with the advance of wireless signaling techniques, regarded by many as the only positive aspect of the year's efforts. For the first time in exercises, the Armoured Force, with 150 wireless sets, had enough equipment to experiment effectively, providing a more complete picture than ever before of the capability of wireless in linking dispersed forces.[83] Surprisingly, the primary method used was wireless telegraphy, yet even that was limited to the signal tanks and vehicles assigned to each unit. Radiotelephone was primarily for staff work and air-to-ground

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[79]B. H. Liddell Hart, "Armoured Forces in 1928," *Royal United Services Institution Journal* (1928): 720.

[80]"The Armoured Force," *Times* (London), 1 September 1928., Liddell Hart, "Armoured Forces in 1928," p. 725.

[81]B. H. Liddell Hart, *The Tanks*, p. 261.

[82]Harold R. Winton, *To Change an Army: General Sir John Burnett-Stuart and British Armored Doctrine, 1927-1938* (Lawrence, KS: University of Kansas Press, 1988), p. 97.

[83]Bond, *British Military Policy,* p. 145.

cooperation.[84] The main reason for this seems to be the reliable range for the Army's sets, which was about 50 miles for wireless telegraphy, but much shorter for radio. Additionally, a great deal of resistance remained among tank officers, who preferred dismounting their tanks and conferring in person to using the cumbersome wireless equipment.

At the end of 1928, four years after the advent of short-wave, five years after its wireless equipment had been designed, and more than ten years since the first military use of radio, the Army found itself still unable to exploit radio-telephony, and just making significant progress on the proper employment of wireless telegraphy in large-scale maneuvers.

The Pinnacle of Tank Radiotelephony, 1931-1934

The Army spent the remainder of the interwar years debating the proper role of a tank force, but the years between 1931 and 1934 represent the closest it came to developing a fluid communication system based on the radiotelephone. Leading up to these important years, the 1929 and 1930 Exercises returned to the Great War model of practicing tank cooperation with infantry units. Though defunct with regard to mobile tank doctrine, the exercises did prove useful for the further perfection of communication by wireless telegraph.[85] The Army continued to receive more of the standard MA, MB, and MC sets, approaching adequate distribution levels. The work was still done almost exclusively by wireless telegraph, and since the signal demands of coordinating tank forces with advancing infantry were necessarily less than those placed on a mobile tank force, telegraphy performed reasonably well. They did manage to conduct a few

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[84]"The Armoured Force," *Times* (London), 6 July 1928.

[85]Great Britain, Parliament, House of Commons, *Memorandum by the Secretary of State for War Relating to the Army Estimates for 1930*, Cmd. 3499, p. 726.; Great Britain, Parliament, House of Commons, *Memorandum by the Secretary of State for War Relating to the Army Estimates for 1931,* Cmd. 3798, p. 705.

experiments with radiotelephony, mainly involving the control of light tank units employed for reconnaissance.[86] The other experiments included artillery spotting and one independent tank exercise, with the artillery exercise being the more important of the two.[87] Prior to this year no radiotelephone sets had even been provided to the artillery units, since the RAF considered wireless telegraphy more suitable to the mission.

Overall, Army leadership still displayed a glaring lack of appreciation for the potential of wireless communication. The most recent versions of the Army's infantry training manual, as well as the newest Field Service Regulations, completely neglected to mention wireless communication of any kind, relying mainly on flag and light signals. Even members of the Royal Corps of Signals seemed to waver on the value of wireless, especially as it existed with the M-series sets. One stated in the Royal United Services Institution *Journal*: "brevity is the soul of W/T...[for] When one wireless or radio-telephone set is working on a given wavelength all others on that wavelength must be silent...."[88] Ironically, Marconi had already developed the equipment that would have negated some of these problems. He completed work on a new amplitude modulated short-wave set for tanks and infantry in 1930. The Type-SB operated on seven to eight meter wavelengths, transmitting and receiving with the help of eight thermionic valves. It would enable two members of tank crews to communicate with each other or to employ telephony or telegraphy. Because of its higher transmitting and receiving frequencies, it was incompatible with existing sets, and would have been useless unless deployed in

[86]"Army Training," *Times* (London), 27 August 1929.

[87]"Work of Radio-Telephones," *Times* (London), 20 March 1929.; *Times* (London), 6 September 1929.

[88]F. S. Morgan, "Modern Communications and Command," *Royal United Services Institution Journal* (1931): 411-412, 415.

sufficient numbers.[89] The Army half-heartedly announced the intention of placing a radio in every tank by 1931, but the Exchequer rejected the proposal.[90]

The year 1931 marks a definite departure in the employment of wireless. Coinciding with the arrival of the Great Slump, the Army revived the Experimental Armoured Force as the First Brigade, Royal Tank Corps under Brigadier Charles Broad. A staunch advocate of the radiotelephone, Broad worked to convince his officers that in spite of the crippling static and mutual interference, it was possible to use wireless operationally and that mobility depended on its proper exploitation.[91] The second half of the 1931 Exercises demonstrated the efficiency possible with proper wireless communication. Tank maneuvering was closely similar to that of ships, in that different formations, such as the Line Ahead or *Ordre Mixte*, allowed better combinations of mobility and firepower under different situations.[92] For the control of his tanks, Broad reduced all necessary commands to a system of one and two letter codes. These were designed to be adaptable to flag, telegraph, or telephone signaling, and would have been especially useful on the M-series radiotelephones since they reduced the number of different words that might be expected over the unreliable system.

This first year saw some experiment with radio, but the telegraph was still the principal means employed.[93] As for set availability, the Ordnance Factory was still delivering the M-series sets, and Broad had enough sets to distribute to most of the company and section commanders.[94] Under his command the First Division almost attained a life of its own. The *Times* correspondent wrote, "A general impression remains

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[89]"Wireless Telephony for Mechanized Armies," *The Electrical Review* (21 November 1930): 873.

[90]Bond, *British Military Policy,* p. 152.

[91]B. H. Liddell Hart, *The Tanks*, p. 324.

[92]W. T. Sargeaunt, "A Suggested Drill for Armoured Formations," *Royal United Services Institution Journal* (1930): 376.

[93]"Army Training," *Times* (London), 17 September 1931.

[94]*Times* (London), 17 September 1931.

of maneuvering tanks, all obviously operating on their own, but controlled by a single design."[95] This was a marked advance over the experiences of 1928 and 1929. Major-General Gwynn wrote of the experience, "In previous years, one was left with the impression that, in order to ensure proper control, tanks must act on a rigid program. Once a situation developed beyond the program, control was lost and unguided initiative led to spectacular but unconvincing Balaclava charges...."[96]

Broad continued his efforts with the M-series sets through 1932 and 1933, culminating in the exercises of 1934. By this time, his men had become proficient in radiotelephony, and though to a lesser degree than in 1931, he still supplied sets to most of his company and section commanders. Army expectations for Broad's Mobile Force had been building, and resulted in a showcase exercise between 18 and 21 September.[97] Composed of a tank brigade, and two armored car squadrons, along with mechanized infantry, artillery, signals, anti-aircraft, and support units, The Mobile Force was the largest wholly mechanized force employed *en masse* in the world. Unfortunately, the exercises were not a success for the Mobile Force. Shortly into the exercise, "enemy" air forces discovered the armored formation, systematically "destroying" the conspicuous grouping of vehicles and forcing the remainder to withdraw without reaching its objective. At 240 tanks and 760 other vehicles, its tremendous size proved to be its ultimate downfall.[98]

Army leaders largely interpreted the debacle as a demonstration of the impracticability of the mobile armored force, and cast serious doubt upon the tank's role. Almost immediately, General Archibald Montgomery-Massingberd, Milne's successor as

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[95]"Army Training," *Times* (London), 5 September 1931.

[96]Charles W. Gwynn, "Army Training, 1931," *Royal United Services Institution Journal* (1931): 730. Balaclava referring to the Crimean region where the cavalry charge that became the subject of Alfred Lloyd Tennyson's "Charge of the Light Brigade" occurred.

[97]"Army Training," *Times* (London), 17 March 1934.

[98]A. G. Cunningham, "The Training of the Army, 1934," *Royal United Services Institution Journal* (1934): 729-730.

CIGS, disbanded the Mobile Force, and with it the last, best British attempt at mobile armored warfare. Doubly unfortunate, Broad's advances in radiotelephone use had been substantial. He refined his 1931 system, enabling radiotelephone traffic to dominate communications. The maneuvers of 1934 represented the last time the Army practiced with anything like a full number of wireless sets. Equally important, this was the last time a commander sensitive to the radiotelephone's potential would get to employ it in large-scale independent tank action.

Stagnation, Panic, and Dunkirk 1935-1940

Behind the scenes, the Slump and the disarmament movement were working against the Army. The Royal Air Force, however, did not silently suffer through the Slump, preferring to energetically garner an ever larger share of the limited funds. In his memorandums to Parliament, the Secretary of State for Air launched several vocal attacks on the stringent situation his service was enduring, indirectly blaming the government's disarmament efforts.[99] In July 1934, the government approved the expansion of the RAF, and general rearmament began.[100]

The Army held its 1935 Manoeuvers, its largest since 1925, without a clear employment doctrine for its forces. The "failure" of the Mobile Force had left a vacuum, so the exercises focused on the tank cooperating with infantry and mechanized cavalry. No clear lessons were divined from the maneuvers, but they did reaffirm that the support contingent for mobile forces must remain small.[101] Wireless communication for the flexible control of tanks was demonstrated effectively on 21 August, but no further

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[99]Great Britain, Parliament, House of Commons, *Memorandum by the Secretary of State for Air Relating to the Air Estimates for 1932*, Cmd. 4026, pp. 225-226.; Great Britain, Parliament, House of Commons, *Memorandum by the Secretary of State for War Relating to the Army Estimates for 1933,* Cmd. 4262, pp. 227-228.; Great Britain, Parliament, House of Commons, *Memorandum by the Secretary of State for War Relating to the Army Estimates for 1934*, Cmd. 4521, p. 228.

[100]"General Service Notes," *Royal United Services Institution Journal* (1934): 177.

[101]"Tanks in Attack," *Times* (London), 28 August 1935.

advance over Broad's efforts occurred.[102] Relevant to this inquiry, the most significant event of 1935 was the introduction of a new mobile short-wave radio in August.[103] Unfortunately, the Army did not issue the "No. 7" in significant numbers, so most units still relied on the old M-series units.[104]

Before long, even the M-sets were scarce, as time and abuse attrited the old equipment. The 1936 Exercises witnessed a tank force severely wasted by neglect and imperial defense needs. Most of the newer equipment had been stripped from the First Tank Brigade and sent to the Mediterranean in response to the Abyssnian Crisis the previous year, leaving only the old Vickers, and a few trucks to represent light tanks. In some instances, signaling had to revert to visual methods due to the shortage of wireless sets.[105] The year 1937 saw a slight improvement in wireless equipment availability with the deployment of a few No. 7 short-wave sets, but even after three years of budget increases, the Army still made no attempts to supply the First Tank Brigade, or any other unit, with a complete short-wave radio system.[106] This negligence is the best proof that the radiotelephone was not a government priority, and that Army officials displayed a glaring lack of appreciation of its value, or potential value, in conjunction with communications for an armored force.

At the end of the year, Secretary of State for War, Hore-Belisha, under the advice of Liddell Hart, canceled Army plans to field an Expeditionary Force.[107] In a surprising move, he made Air Defence of the home islands first priority for the British Army. Royal Air Force ascendancy was complete; with this decision, the Army became a supporting land arm of the RAF with no strategic mission. Naturally, the Army leadership disagreed

[102]"Army Training," *Times* (London), 22 August 1935.
[103]"Modern Developments," *Times* (London), 8 August 1935.
[104]B. H. Liddell Hart, *The Tanks*, p. 350.
[105]"Tanks on the Plain," *Times* (London), 3 September 1936.
[106]"Tank Brigade Training," *Times* (London), 1 October 1937.
[107]"Army Notes," *Royal United Services Institution Journal* (1938): 442.

with this move, and fought throughout 1938 and part of 1939 to have it rescinded. In February 1939, Chamberlain reluctantly agreed to field an Expeditionary Force and fund the expansion.[108]

In the end, the British Army went to war never having practiced with, and having never employed a comprehensive, radiotelephone-based communications system. More surprisingly, according to the War Office's official World War II history, "When the BEF [British Expeditionary Force] went to France in 1939, wireless was still regarded with a great deal of suspicion, principally owing to its lack of secrecy, and the fear of giving away the position of headquarters...."[109] The latter fear arising from the effectiveness of radio direction finding, which had been further perfected since the previous war. In addition, wireless operation was still plagued with inefficiency stemming from a "lack of confidence...which was often displayed by the users."[110] The mistrust seems directly related to the inferior equipment, most of which was still of 1924 design. The British did not widely distribute short-wave radio to its tank units until it sent the Expeditionary Force, and while FM sets were not yet perfected for the field, British tanks would not receive them in numbers until after the war.

The BEF sent to France in 1939 consisted of thirteen infantry divisions, and one regiment of 50 heavily-armored Mk I Infantry Tanks, the 4th Royal Tank Regiment (RTR). The 7th RTR, with twenty-seven Mk I's, twenty-three Mk II Cruiser Tanks, and seven light tanks, did not arrive until the first week in May, 1940.[111] The Germans attacked Belgium and France on 10 May, driving the Allies back with unprecedented speed, and severing British lines of communications, leaving only Dunkirk and two other

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[108]Bond, *British Military Policy,* p. 293.

[109]*The Second World War, 1939-1945: Signal Communications*, p. 168.

[110]Ibid., p. 176.

[111]B. H. Liddell Hart, *The Tanks: The History of the Royal Tank Regiment and its Predecessors Heavy Branch Machine-Gun Corps and Royal Tank Corps, 1939-1945*, vol. II. (New York: Frederick A. Praeger Publishers, 1959), pp. 6-7.

Channel ports as an escape route. Desperately seeking to cover its retreat, the BEF, commanded by Major-General G. LeQ. Martel, launched a local counterattack near Arras on 21 May, constituting the first, and last, major British tank action in France until 1944.

Designated the 1st Tank Brigade under the command of Brigadier Douglas Pratt, the 4th and 7th Regiments had been decimated by mechanical failures on the march to their staging area, and had only 58 serviceable Mk I's and 16 Mk II's on the eve of the battle. The Mk II's were distributed among the Mk I's to provide fire support, and the light tanks, carrying No. 7 short-wave sets, were for command and reconnaissance.[112] The concept of operation was vintage World War I, with the 1st Brigade's intended role being that of a mobile reserve for the infantry, to attack at the critical time and place to facilitate the advance.[113] The British attack was hardly lightening warfare. The Mk I's, capable of only eight miles per hour, determined the rate of advance. The 1st Brigade hit the supply and infantry columns of Rommel's 7th Panzer and the *SS Totenkopf* divisions, disrupting the German advance. While Martel showed signs of Rommel's command philosophy, commanding his forces from a wireless car, communication between the Mk II's and Mk I's was through visual signals, and tankers still dismounted to confer with infantry. Although his advance was disrupted, Rommel quickly stalled the British advance with significant losses, and harassed their tanks with Stuka dive bombers.[114] The BEF was swept from the Continent, its dramatic escape from Dunkirk partially enabled because of the Arras counterattack[115] The British proved they could fight gallantly, but they also demonstrated that their interwar work with mobile armored formations, and the critical communications between and within them, was sadly inadequate.

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[112]Ibid., p. 12,

[113]Larson, *The British Army and the Theory of Armoured Warfare,* pp. 235-236.

[114]Alistair Horne, *To Lose a Battle: France 1940* (Boston, MA: Little Brown, and Co., 1969), p. 501.

[115]Robert Jackson, *The Fall of France, May-June 1940*, (London: Arthur Baker Limited, 1975), p. 126.

Chapter III

THE UNITED STATES

The Interwar Situation

When American forces hit the beach in North Africa on 8 November 1942, they fared better than BEF had in its debut, but things were far from perfect. As later action against the Germans demonstrated, the Army had organizational problems, some deadwood in the command structure, and the M3 tank was inferior to its opposition. One bright spot for the TORCH landings, however, was the SCR-509 FM radio set. During the landing at Safi, Morocco, instead of using the AM sets officially designated for the purpose, the troops improvised a communications net based on the push-button tuned FM armored division equipment.[1] The SCR-500 series sets fielded by American armored forces from their first action were more advanced than any communications equipment employed by any other combatant for the remainder of the war.

The influences driving radio use and development in the United States had many similarities to those experienced in Great Britain. Like Britain, the United States was relatively secure from the possibility of a land invasion, and felt its main defense concerns required a naval solution. Its people had inherited a disdain for large standing armies, and after the Great War, never again wished to become involved on the Continent. While emerging from World War I economically stronger than their European Allies, the American people preferred stringency in government during the twenties, and

[1]George Raynor Thomson, Dixie R. Harris, Pauline M. Oakes, Dulany Terrett, *The Signal Corps: The Test,* United States Army in World War II (Washington D. C.: Office of the Chief of Military History, Department of the Army, 1957), p. 361.

experienced its share of hardship in the early 1920's, and again in the 1930's. The US Air Service coveted the RAF's independence, and through its own quest for independence, absorbed most of the attention and money the public was willing to devote to the military. Internally, though to a lesser degree than in the British Army, the American Army suffered from small-mindedness and lack of vision. Considering the numerous similarities, the major difference between the two nations' interwar experiences was their behavior on the threshold of war.[2]

The purpose of the following section parallels that of its counterpart on the British Army: to identify the four influences on radio development, thereby allowing a suitable discussion of exactly how their interaction shaped US armored force communications. Again, these influences are public attitudes, economics, internal Army attitudes, and air power development. In the United States, however, the prospect of war, rather than triggering appeasement, precipitated a reaction that largely overshadowed other concerns after 1940.

America's experience in World War I, while paling next to the collective horror endured by the other combatants, was distasteful enough to encourage the public to disavow interventionism, and revert to traditional notions of splendid isolation. The official expression of this feeling found itself in the National Defense Act of 1920. In the effort to digest the war's lessons, a considerable struggle emerged among forces in the army representing the Chief of Staff on one hand, and the Commander in Chief of the AEF, General of the Armies John J. Pershing on the other. Both camps advocated some form of universal military service.[3] Congress however balked on the proposal as overly militaristic, and approved a maximum army strength of 280,000, half of what the army

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[2]Ronald Spector, "The Military Effectiveness of the US Armed Forces, 1919-1939," *Military Effectiveness Volume II: The Interwar Period*, eds. Allan R. Millet, and Williamson Murray (Boston, MA: Allen and Unwin, 1988), pp. 70-97.

[3]Russel F. Weigley, *History of the United States Army, Enlarged Edition* (Bloomington, IN: Indiana University Press, 1984), p. 399.

requested. In reality, public sentiment did not allow even this minimal number until 1940. Strategically, the greatest threat to United States' possessions was the growth of Japanese naval power in the Pacific, but even a palpable threat to the Philippines was not enough to prompt major naval spending.

The Army accompanied its significant wartime technical achievements in radio and other areas with a prodigious materiel buildup, which in addition to being too late to influence the war, also contributed to postwar modernization problems. In another expression of public opposition to further military expenditure, the Army was encouraged to exhaust its tremendous surplus before new equipment would be procured. The army was effectively placed on its own Ten Years' Rule, for no new rifle types, tanks, or radios for those tanks were procured until after the Great Depression abated in 1934.[4] In fact, the army built only thirty-five tanks during the entire period between 1920 and 1935, most of which were hand-built experimental types.[5] These deficiencies added frustration to the efforts of the hard-pressed officer corps, who suffered slow promotion rates, and had to care for their often impoverished enlisted troops.[6]

Coupled with the public's reluctance to spend large amounts on the military, the economic crisis that struck in October 1929 had a significant effect on the nation's interwar military evolution. The main years during which the army suffered the most monetarily from the depression were 1932 through 1935. Between 1931 and 1934, the Army's total military activity appropriation was cut from $ 367,548,000 to

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[4]Spector, "Military Effectiveness," p. 75.; U. S., War Department, *Radio Sets, Types SCR-189 and SCR-190, Technical Regulation 1210-70* (Washington, D. C.: U. S. Government Printing Office, September 11, 1934), p. 1.; U. S., War Department, Douglas A. MacArthur, *Annual Report of the Chief of Staff, 1935*, in *Report of the Secretary of War: To the President, 30 June 1935* (Washington, D. C.: U. S. Government Printing Office, 1935), p. 53. pp.41-74.

[5]Blumenson, *Patton Papers, Vol. 1*, p. 960.

[6]Spector, "Military Effectiveness," p. 72.

$292,846,000.[7] Congress approved the first major increase in 1935, increasing the 1936 appropriation for military activities to $ 343,465,000.[8] The 1935 budget vote indicated a recognition of the dismal state of military affairs, not a willingness to go to war. On the contrary, Congress voted for a number of neutrality acts between 1935 and 1939, hoping to make its intentions clear to Europe.[9]

In the face of extreme budgetary stringency, the army, principally under the guidance of Chief of Staff General Douglas A. MacArthur, preferred to protect its trained personnel to pursuing mechanization and technical advancement. This tendency, the widespread requirements of national and territorial defense, and the 3,000-plus officers required to staff the Civilian Conservation Corps after 1933, dissipated manpower. During the Great Depression, the Army was no more than a skeleton force dissipated among the many active outposts, and largely unable to conduct any meaningful training.[10] Though he opposed full-scale mechanization on the grounds that the vehicles would quickly become obsolete, MacArthur consistently advocated equipping experimental units, correctly noting in 1935, "an army cannot be properly prepared to use and cooperate with modern fast-moving tanks if it has nothing except the cumbersome types left over from the World War."[11] Preservation being the ultimate goal, however, innovation was pushed to the side, and the various arms sought to demonstrate their

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[7]U. S., War Department, Douglas A. MacArthur, *Annual Report of the Chief of Staff, 1931*, in *Report of the Secretary of War: To the President, 30 June 1931* (Washington, D. C.: U. S. Government Printing Office, 1931), p. 86.; U. S., War Department, Douglas A. MacArthur, *Annual Report of the Chief of Staff, 1932*, in *Report of the Secretary of War: To the President, 30 June 1932* (Washington, D. C.: U. S. Government Printing Office, 1932), p. 118.

[8]U. S., Congress, House, *War Department Appropriation Bill, Fiscal Year 1936: Report to Accompany H. R. 5913*, 74th Cong., 1st sess., 1935, H. Rept. 159, p. 6.

[9]Millett and Maslowski, *For the Common Defense*, p. 405.

[10]MacArthur, *Report of the Chief of Staff, 1932*, pp. 59-60.; U. S., War Department, George H. Dern, *Report of the Secretary of War: To the President, 30 June 1933* (Washington, D. C.: U. S. Government Printing Office, 1933), p. 8.

[11]MacArthur, *Report of the Chief of Staff, 1935*, p. 51.

fundamental importance to national defense in their traditional roles. All of these problems were exacerbated by a tendency among the military leadership to plan for expected rather than needed funds, and to publicly follow the lead of their Commander-in Chief on budgetary matters.[12]

Rather than hang on in quiet desperation, the Air Corps took its needs in front of the public. The Air Service's unofficial mouthpiece was Brigadier General William Mitchell, who began advocating a separate air force in 1919.[13] While Mitchell was fanning the flames of public interest, the real progress toward a separate air force was accomplished by the Air Service Chief Major General Mason M. Patrick. His moderate advocacy of air power led to the creation of the Air Corps in 1926, and ultimately the General Headquarters Air Force in 1935.[14] Consistent with its more independent status, and wishing to further augment it, theorists at the Air Corps Tactical School followed the RAF's lead in emphasizing the strategic air mission. The Air Corps correspondingly deemphasized tactical aviation, and America entered World War II with inadequate fighter and attack aircraft types. Close air support doctrine for armored formations had also been neglected, as army officials would discover during the 1941 maneuvers.

America's pre-war maneuvers, known officially as the GHQ Maneuvers, were a tremendous achievement when one considers the poor state of military preparedness that existed prior to 1940. In 1934, President Roosevelt finally recognized the dismal military situation, widely regarded as the lowest state of readiness in United States' history, and began a modest rearmament. Initially, this consisted of a naval building program and the

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[12]John W. Killigrew, *The Impact of the Great Depression on the Army* (New York: Garland Publishing, 1979), pp. C1-C8.

[13]Thomas H. Greer, *The Development of Air Doctrine in the Army Air Arm, 1917-1941* (Washington, D. C.: U. S. Government Printing Office, 1985), p. 17.

[14]Ibid., p. 29.

authorization to field new tank types in 1935.[15] The mechanized cavalry units then representing the army's experimental armored formations received full complements of the new tanks and accompanying radio sets in 1938, finally permitting useful large-scale exercises.[16] When Roosevelt declared a state of national emergency in 1939, American troop strength was still under the authorized number, but rearmament slowly gained momentum. After the German assault of France, the public awakened, efforts were redoubled, and large-scale exercises with mobile armored forces were attempted for the first time.[17]

The approach of war was seen as inevitable after 1940, and popular sentiment, widely supportive of Hitler's defeat, assumed that hard fighting would be required on land and sea. With the exception of a debate over Lend-Lease and rearmament, previously dominant economic factors passed into the background. Removing economic constraints also eased the negative influence of the Army Air Forces, allowing the army to allocate sufficient funds to its ground forces. To illustrate the contrast, in 1938 the army ranked eighteenth in the world in numerical strength, and Chief of Staff Malin Craig complained that "the limited amounts appropriated annually for armament were devoted largely to the procurement of aircraft."[18] By the end of May 1940, Roosevelt had recommended $2,000,000,000 for military purposes, and in just over a year, army strength ballooned to 1.4 million troops.[19]

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[15]Millett and Maslowski, *For the Common Defense*, p. 405.; U. S., War Department, Douglas A. MacArthur, *Annual Report of the Chief of Staff, 1934*, in *Report of the Secretary of War: To the President, 30 June 1934* (Washington, D. C.: U. S. Government Printing Office, 1934), p. 40.

[16]"The Mechanized Cavalry Takes the Field," *The Cavalry Journal* (July-August 1938): 291.

[17]Millett and Maslowski, *For the Common Defense*, p.415.

[18]U. S., War Department, Malin Craig, *Annual Report of the Chief of Staff, 1938*, in *Report of the Secretary of War: To the President, 30 June 1938* (Washington, D. C.: U. S. Government Printing Office, 1938), p. 29.

[19]U. S., War Department, George C. Marshall, *Biennial Report of the Chief of Staff of the United States Army, 1 July 1939 to 30 June 1941: To the Secretary of War*, in *Biennial Reports of the Chief*

While reactionary officers still existed in its ranks, Army leadership had the advantage of watching Hitler's armored attacks defeat most of Europe. Not only that, but visionary leaders and talented mobilization planners had laid the groundwork for rapid recovery from the years of public disinterest, Air Force predominance, and economic hardship. With the exception of its misguided anti-tank doctrine, army leaders made generally correct doctrinal adjustments, and ultimately sent a formidable combat force to Europe based on sound mobile armored doctrine. Within this framework, the Signal Corps and armor practitioners sought to produce radio capable of effective command and control of US armored forces.

Postwar Doldrums, 1919-1926

The seven years immediately after the war represent a period of relative inactivity in radio and armor development that finally ended with the surge of interest that followed the British Army's 1925 Manoeuvers.[20] Even though little was accomplished in terms of experimentation and field testing, the legal and intellectual trends established during this period shaped radio communications for most of the interwar period.

The most important action was the passage of the National Defense Act of 4 June 1920. Reflecting Pershing's influence, and the sentiments of the General Staff, the law reaffirmed the Infantry's primary role, and contained three important measures reflecting that philosophy. First, it created the Air Service as a new branch, increasing the independence air units had under the Signal Corps, but leaving it within Army control. Second, it dissolved the Tank Corps as a branch, and assigned its various units and

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of Staff of the United States Army: To the Secretary of War, 1 July 1939-30 June 1945 (Washington, D. C.: U. S. Government Printing Office, 1996), pp. 6-7.

[20]U. S., War Department, Dwight F. Davis, *Report of the Secretary of War: To the President, 30 June 1925* (Washington, D. C.: U. S. Government Printing Office, 1925), pp. 24-25.

equipment to the Infantry.[21] While the tank's role during the war had indeed been infantry support, this measure downplayed future independent roles, and decreased chances that tank development would receive adequate funding. Finally, it limited the span of control of the Signal Corps, which had been in charge of all World War I signal communication. Under the reorganization, Signal Corps responsibility extended only to the division level, removing its official stake in tactical communications development.[22]

In 1923, the Infantry's role was further solidified with the publication of the Army's Field Service Regulations (FSR), Field Manual 100-5. The Field Service Regulations contain the Army's organizational philosophy and employment concepts, and the Army felt largely satisfied with this version until 1941.[23] As stipulated by the National Defense Act, the 1923 FSR retained the square division, designed with the Western Front in mind, as its fundamental fighting unit. The mission of the Infantry was the "general mission of the entire force," relegating the other arms to the support of that mission.[24] Combined arms employment, or the coordinated use of all arms, was essential to Infantry success. Within this framework, the tank was to increase the "operative mobility" of the infantry, as it was simply a means to "transport infantry weapons under artificial cover."[25] Any independent role for tanks was ignored, since the "individual fighting man," not machines, formed the basis of army strength.[26] The FSR also

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[21]U. S., Congress, *National Defense Act, Approved 3 June 1916 As Amended to Include 4 March 1927, with Related Acts, Decisions, and Opinions* (Washington D.C.: U. S. Government Printing Office, 1927), p. 27, section 17.

[22]Terrett, *The Emergency*, p. 23.

[23]U. S., War Department, U. S. Army, *Field Service Regulations, FM 100-5* (Washington D. C.: U. S. Government Printing Office, 1923).; U. S., War Department, U. S. Army, *Field Service Regulations (Tentative), FM 100-5, Operations* (Washington D. C.: U. S. Government Printing Office, 1939).; U. S., War Department, U. S. Army, *Field Service Regulations, FM 100-5, Operations, 22 May 1941* (Washington D. C.: U. S. Government Printing Office, 1941).

[24]*FM 100-5, 1923*, p. 11.

[25]Ibid., p. 13.

[26]Ibid., p. 12.

addressed radio communications, and, realizing the status of contemporary radio equipment, assigned it a secondary role to line telegraphy and telephony. Radios would provide communications links for redundancy, long distance, and heavily shelled combat areas. Signal tanks, rather than being deployed for the control of tank units, were "especially suited to employment in zones of heavy hostile fire" as part of the "general system of infantry communications."[27]

The tanks and radio sets possessed by the Tank Corps were mostly items designed for World War I employment, and congressionally authorized after the Armistice to fulfill contract obligations. In 1920, the army had 618 US-produced M1917's, as well as 32 leftover British Mk V's, and 213 French Renault FT's. The M1917 was a slightly improved model of the Renault, and the only tanks produced from the original 4,400 ordered.[28] The Tank Corps also had 10 modified M1917's equipped with a special turret for carrying the standard, and only, tank radio until 1934, the SCR-78A Tank Radiotelegraph.[29] The SCR-78A was designed specifically for M1917 use in 1918.[30] It contained seven vacuum valves, and transmitted on wavelength of 500 to 1100 meters using 15 watts of power. It could conceivably facilitate tank to tank, tank to aircraft, and tank to headquarters communication. The range for tank intercommunication was only rated at 3 miles, and a maximum of 6 miles from tank to headquarters.[31] Although ahead for its time, the SCR-78A was not even capable of transmitting voice signals, and even with the more distinguishable telegraph signals, engine interference greatly limited

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[27]Ibid., pp. 29-30.

[28]U. S., War Department, Samuel D. Rockenbach, *Report of the Chief of the Tank Corps*, in *Report of the Secretary of War: To the President, 30 June 1920* (Washington, D. C.: U. S. Government Printing Office, 1920), p. 1891.; Chamberlain and Ellis, *Pictorial History of Tanks*, p. 169.

[29]Rockenbach, *Report of the Chief of the Tank Corps*, p. 1894.

[30]U. S., War Department, U. S. Army Signal Corps, *Tank Radio Telegraph Set, Radio Pamphlet No. 24*, (Washington, D. C.: U. S. Government Printing Office, 20 April 1919), p. 3.

[31]Ibid.

reception.[32] Prior to losing independent status, the Tank Corps carried out a number of experiments with this set, and improvised radiotelephone sets. One instance tested "extended radiotelephone conversation from tank to tank, back to headquarters, and with airplanes," finding the results "very satisfactory."[33]

After it was amalgamated with the Infantry, the Tank Corps lost the drive for such experiments, and some of its best minds. Captain Dwight Eisenhower, and Colonel Patton left the Tank Corps for the Infantry and the Cavalry respectively. Open discussion on the independent tank role seems also to have been discouraged, as evidenced by an often-quoted allegation by Eisenhower that he was instructed by the Chief of Infantry not to publish "anything incompatible with solid infantry doctrine" or face court-martial.[34] Patton reportedly received the same treatment, and spent most of the interwar years alternately floating the possibilities of mechanized forces, and stressing the their limitations. The Secretary of War even reflected the prevailing mindset in his 1922 report expressing support for work on tanks and aircraft, but pointedly stating, "We should not slack in the training of our citizens in the simplest technique of war, the handling of America's weapon--the rifle..."[35] Further evidence of a closed attitude toward tank development can be seen in articles in the branch journals.

Possibly as a result of the World War experience, which found horse cavalry playing an insignificant role, articles in the *Cavalry Journal* seemed especially insecure about the future of the arm. Most of the relevant material asserted the continuing need for cavalry in its traditional role and formation, and the corresponding irrelevance of mechanized forces to future war. According to various articles, the Great War showed

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[32]Ibid.

[33]Rockenbach, *Report of the Chief of the Tank Corps*, p. 1894.

[34]Dwight D. Eisenhower, *At Ease: Stories I Tell to Friends* (Garden City, NY: Doubleday, 1967), p. 173.

[35]U. S., War Department, John W. Weeks, *Report of the Secretary of War: To the President, 30 June 1922* (Washington, D. C.: U. S. Government Printing Office, 1922), p. 21.

that "American theories for the training and use of cavalry are thoroughly sound."[36] More definitively stated: "As for gas and tanks, their use will be restricted to siege operations or to the kind of warfare that the present war brought about, but which will hardly ever occur again."[37] One colonel went even further, asserting that the technological advancements associated with the war, machine guns and artillery specifically, "made cavalry attacks possible in situations which before the war would have been considered impossible."[38] Preserving the place of cavalry had taken priority over considered thought on the potential changes brought forth by the war.

To be fair, certain officers objectively considered cavalry's future as altered by technology. Patton's opinion, though more balanced, was nonetheless skeptical. According to him, tank advocates were "right within limits; only they were overconfident of the effectiveness of their favorite weapon."[39] Major Bradford Chynoweth, rightly identified the World War I role as one of infantry support. Future tanks would be able to move at high speed, coordinated by radio, and armed to neutralize enemy defense works and tanks. Cavalry, therefore, should be open to the possibility of tanks operating in conjunction with horse cavalry.[40] In response, Patton characteristically pointed out cavalry strengths, but ended by advocating a separate tank arm. "[G]ive it [the tank] half a chance, over suitable terrain and on proper missions, and it will mean the difference between defeat and victory...."[41]

For mobile work within the cavalry, pack sets were judged inconvenient because of their weight, and the necessity of removing them from the horse, then manually tuning

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[36]Guy V. Henry, "Mobility," *The Cavalry Journal* (April 1920): 23.

[37]A. J. Tittigen, "The Future of Cavalry" *The Cavalry Journal* (April 1920): 68.

[38]Hamilton S. Hawkins. "The Role of Cavalry," *The Cavalry Journal* (October 1920): 265.

[39]George S. Patton, "What the World War Did for Cavalry," *The Cavalry Journal* (April 1922): 165.

[40]Bradford G. Chynoweth, "Cavalry Tanks" *The Cavalry Journal* (July 1921): 247-251.

[41]Patton, "Comments on 'Cavalry Tanks,'" *The Cavalry Journal* (July 1921): 252.

them before operation.[42] While official Signal Corps recommendations emphasized radio as the principal means of cavalry communications as early as April 1921, authors did not begin recording positive experiences until the SCR-130 series of cavalry radios appeared in 1923.[43] Prior to this even Signal Corps troops saw radio as second in importance to mounted or motorcycle couriers. Their effectiveness was fortunately not lost on Major Adna R. Chaffee, America's foremost armor practitioner until his 1941 death. He wrote, regarding the 1923 1st Cavalry Division Maneuvers: "Radio formed the principal means of communication between the Division Headquarters, the home stations, and the several columns on the march."[44] When mounted in light trucks, the division headquarters sets "met every demand." Patton, however, remained unconvinced, complaining that the pack radios had "too much static."[45]

The sets that made this turnaround possible, as well as four additional aircraft sets, were designed in the Signal Corps Laboratories established at Camp Alfred Vail, later renamed Fort Monmouth, New Jersey.[46] In addition to indicating army priorities, these sets represent quality effort of the Signal Corps in spite of patent limitations on superheterodyne technology, and meager research funds. The Radio Development Section had been established as part of the Laboratories in 1920, at roughly the same time as its British counterpart.[47] As indicated by its name, Radio Development Section pursued more practical work than the Radio Research Board conducted for the War Office. In 1920, the Signal Corps was focused on providing enough radios for the army.

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[42]William C. Sherman, "Cavalry and Aircraft," *The Cavalry Journal* (January 1921): 29.

[43]O. S. Albright, "Cavalry Signal Communications," *The Cavalry Journal* (April 1921): 147.

[44]Adna R. Chaffee, "The Maneuvers of the 1st Cavalry Division, September-October 1923," *The Cavalry Journal* (April 1924): 135.

[45]George S. Patton, "Armored Cars with Cavalry," *The Cavalry Journal* (January 1924): 9.

[46]Terrett, *The Emergency*, p. 29.

[47]U. S., War Department, Newton D. Baker, *Report of the Secretary of War: To the President, 30 June 1920* (Washington, D. C.: U. S. Government Printing Office, 1920), p. 1255. pp. 1237-1298.

Of primary concern at this stage was completing the orders placed during the war, and securing enough technical experts for quality work. The Navy Department provided constant competition for qualified people to staff the laboratories.[48] Most of the research effort was devoted to perfecting equipment for employing Armstrong's superheterodyne receiver, which was to be included for the first time in the SCR-130 series cavalry and aircraft sets. Relevant projects included multistage amplifier research, and producing quality regenerative vacuum tubes.[49]

By 1922, the Signal Corps was already suffering from the postwar economic crisis. It was not receiving enough funds for research and was critically understaffed, prompting official complaint from Major General George O. Squier, the Chief Signal Officer.[50] Radios, however, were not among the army's materiel priorities. In addition to the absence of funds for Signal Corps equipment, the army listed recruitment, maintenance of existing supplies and reserve ammunition, and coastal defense artillery as its main priorities for 1924 and 1925.[51] The Chief of Infantry even had work on tank radios blocked, preferring to keep the old ones to maintain operational proficiency among his tank radiomen.[52]

Work at the Signal Corps had to continue, and plans had to be made for using the existing technology in a coherent communications system for the organizational scheme adopted with the National Defense Act. For the square division, line telegraph and telephone links were the primary means of communication, and were arranged in a grid.

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[48] *Report of the Chief Signal Officer, 1920*, p. 1259.

[49] Ibid., pp. 1259-1260.

[50] U. S., War Department, George O. Squier, *Annual Report of the Chief Signal Officer, 1922*, in *Report of the Secretary of War: To the President, 30 June 1922* (Washington, D. C.: U. S. Government Printing Office, 1922), p. 258.

[51] U. S., War Department, John W. Weeks, *Report of the Secretary of War: To the President, 30 June 1924* (Washington, D. C.: U. S. Government Printing Office, 1924), p.13.; Dwight F. Davis, *Report of the Secretary of War: To the President, 1925*, p. 16.

[52] "Communications Equipment for Light Tanks" *Infantry Journal* (January 1927): 184.

The division and its subordinate brigades, artillery batteries, and forward positions were placed at established intervals from the rear to the front. Divisional sectors of this type would then be set adjacent to each other and extended along the entire front. Inherently inflexible and intended for Great War-type positional warfare, this grid communication scheme, was much like the one the British Army kept through 1940. It could not take advantage of radio communication.

Of the two types, radiotelegraph was more reliable and generally available at this point. It was thus preferred over the radiotelephone, which was used mainly for air-to-air and air-to-ground liaison. From division headquarters, radio communication would only extend as far as the battalion, individual aircraft, and tank companies.[53] For tanks, this meant that one radio would have to suffice for the control of nine main-line vehicles, making necessary the extensive reliance on runners and visual signals.[54] The Infantry, however, had discontinued signal tanks altogether, preferring to rely on more traditional means for all tank communication.[55] Signal concepts for 1926 were still wedded to the primary role of infantry and the inferior nature of available radio equipment.

The Experimental Mechanized Force and the SCR-78A, 1927-1930

Weeks' successor as Secretary of War demonstrated a more open-minded approach to the possibilities of technology as they applied to warfare. After traveling to England for the 1927 British Army Manoeuvers, Dwight F. Davis returned advocating similar combined arms training involving tank, air, and ground forces. The following year, he authorized the organization of the Experimental Mechanized Force (EMF)

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[53]Duncan Hodges, "Radio Communication in the Division," *Signal Corps Bulletin* (June 1925): 22.

[54]U. S., War Department, U. S. Army Signal School, *Army Organization and Organization of Signal Communication Units, Signal School Pamphlet No. 16* (Ft. Monmouth, NJ: The Signal School, U. S. Army, 1931).

[55]Hodges, "Radio Communication in the Division," p. 25.

composed of infantry, tanks, Air Corps, Field Artillery, and antiaircraft units, among others.[56] A surge of interest from professional military circles, especially among members of the Infantry, accompanied the tank Corps' rebirth. Until MacArthur disbanded the Experimental Armored Force in 1931, the army held a series of exercises to determine the value of mobile armored formations, and how they might best be controlled in combat.

Unfortunately for the army, its internal professional interest was not matched by public interest, which had become enthralled with air power. Even in the 1928 Report of the Secretary of War, which announced the formation of the new mechanized force, the Air Corps expansion and a record flight from California to Hawaii received more emphasis.[57] If 1928 was an epiphany of sorts for armored warfare proponents, 1925 was an equivalent turning point in the Air Service's continuing battle for independence. While General Pershing and the National Defense Act rebuked the wartime Air Service chief's early efforts to secure more autonomy, Brigadier General Mitchell called for an independent air force with a strategic mission.[58] In a 1922 exercise he dramatically sank the captured German battleship *Ostfriesland* from the air, challenging traditional Navy superiority, and catching the public eye.

No major policy changes occurred, however, and air power advocates continued to press for reform. Their efforts culminated in an eleven month Congressional hearing conducted by the Lampert committee, which began in March 1924. After hearing testimony favoring air force independence, the committee recommended granting independent status.[59] Before releasing its conclusions, Major General Patrick

[56]U. S., War Department, Dwight F. Davis, *Report of the Secretary of War: To the President, 30 June 1928* (Washington, D. C.: U. S. Government Printing Office, 1928), p 4.

[57]Ibid., pp. 2-4.

[58]Greer, *Development of Air Doctrine,* pp. 23, 17.

[59]Ibid., p. 28.

recommended against separation, prompting Mitchell to allege treasonous neglect of airpower. His court martial was a controversial showcase of air power theory, and Congress felt compelled to grant at least the level of autonomy Patrick requested, creating the US Army Air Corps on 2 July 1926.[60]

The high public interest during 1926 also resulted in the approval of a five-year building program, and Air Corps funding increased dramatically. Between 1930 and 1931, funding jumped by approximately $9,000,000 dollars to $38, 042, 000, at which point it was 10 percent of army military expenditure.[61] This proportion increased to 20 percent by 1933.[62] Exercises in 1926 and 1927 featured the new air arm, while conventional army formations had insufficient funds for large-scale maneuvers.[63] The situation was such that the Chief of Staff, though admittedly hostile to the Air Corps, officially criticized the preferential treatment it received.[64] Army officials also felt in 1930 that personnel transfers from conventional arms to Air Corps expansion was seriously interfering with army training, and this at a time when experiments with the Mechanized Force had just gained momentum.[65]

The Experimental Mechanized Force assembled at Ft. Meade, Maryland on 1 July 1928 for testing a "self-contained unit of great mobility, great striking power, and limited holding power.[66] Tanks, not the infantry, constituted the primary element of this

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[60]Ibid., p. 29.

[61]U. S., War Department, *Reports of the Secretary of War: To the President* (Washington, D. C.: U. S. Government Printing Office, 1920-1931).

[62]Dern, *Report of the Secretary of War, 1933*, p. 33.

[63]U. S., War Department, J. L. Hines, *Annual Report of the Chief of Staff, 1926*, in *Report of the Secretary of War: To the President, 30 June 1926* (Washington, D. C.: U. S. Government Printing Office, 1926), p. 45.; U. S., War Department, Charles P. Summerall, *Annual Report of the Chief of Staff, 1927*, in *Report of the Secretary of War: To the President, 30 June 1927* (Washington, D. C.: U. S. Government Printing Office, 1927), p. 51.

[64]*Infantry Journal* (December 1926): 598.

[65]U. S., War Department, Patrick J. Hurley, *Report of the Secretary of War: To the President, 30 June 1930* (Washington, D. C.: U. S. Government Printing Office, 1930), p. 3.

[66]"Basic Principles for Experimental Mechanized Force," *The Cavalry Journal* (July 1928): 440.

offensive force, with cooperating arms supporting tank units in operations characterized by "Surprise, speed, and depth of penetration."[67] As a member of the Training Division of the General Staff, Major Adna Chaffee sought funding and designed the training program for the experiment, which was more for devising "technical methods for application by such a force to tactical problems" than for actually finding solutions.[68][69]

Communications was an important aspect of the targeted tactical problems. Command and control naturally involved the means of communication to be employed, the most suitable types of command posts, means of transmitting orders, and means of liaison with cooperating forces.[70] Tactical formations would also depend to some degree on the effectiveness of communications equipment and methods. Offensive action involved coordination between tank formations and battlefield reconnaissance. Finally, artillery support required observation aircraft, and knowledge of friendly troop location.[71] Nearly every military function is dependent on communication, but Army officials were realizing that the high speeds possible with the internal combustion engine made instantaneous personal communication essential. Radio alone could allow such flexibility. The tanks and radio equipment available to the EMF made this difficult to envision.

In 1928, the EMF's tanks were the remaining M1917's, the Renaults still operating, and four experimental tanks. The T1E1 experimental tanks, redesignated the M1, traveled at 15-20 mph cross-country, and weighed less than 10 tons. The M1 design became the basic tank fielded by the US Army for the late interwar period, but improved

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[67]Ibid.

[68]Mildred Hanson Gillie, *Forging the Thunderbolt: A History of the Development of the Armored Force* (Harrisburg, PA: The Military Service Publishing Company, 1947), pp. 29-30.

[69]"Tactical Work of Experimental Mechanized Force Outlined," *The Cavalry Journal* (July 1928): 441.

[70]Ibid.

[71]Ibid., p. 442.

versions were not procured in numbers until 1935.[72] Army officials expected the four new machines then available to allow the EMF to test the possibilities of "modern" tank formations.[73] The EMF's radio equipment was hardly any better, since the vintage SCR-78A still equipped the company-level signal tanks. Consequently, the Experimental Mechanized Force provided experience with combined armored forces, but those experiences only faintly represented the possibilities for armored forces. Conditions for the US Army were still better than those in early postwar Germany, whose military devised *Blitzkrieg* through exercises with cardboard "tanks" mounted on bicycles.

One of the first lessons the maneuvers revealed was the inability of light tanks to cooperate with cavalry troops. While Cavalry leaders recognized the value of tank formations as auxiliaries to horse troops, the M1917's 1.5 mph cross-country speed was too slow to keep up.[74] The exercises of 1928 were extremely disappointing. The Chief of staff, General Charles P. Summerall, concluded that "The speed of the tanks was so low and the materiel so obsolete, that little knowledge of value was gained."[75] After the 1928 training season, he issued a call for mechanization: the army needed more money for maneuvers and better research funding. As Summerall put it, "Any great nation which fails to provide for the utilization of mechanization...must suffer the consequences of neglect in future war."[76] A Tank School tactical instructor felt that the exercises demonstrated clearly the need for faster tanks, mobile artillery, and freedom from infantry

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[72] MacArthur, *Report of the Chief of Staff, 1932*, p. 84.

[73] "Basic Principles for Experimental Mechanized Force," p. 441.

[74] George Dillman, "1st Cavalry Division Maneuvers," *The Cavalry Journal* (January 1928): 63.

[75] Charles P. Summerall, "New Developments in Warfare," *The Cavalry Journal* (February 1931): 8.

[76] U. S., War Department, Charles P. Summerall, *Annual Report of the Chief of Staff, 1929*, in *Report of the Secretary of War: To the President, 30 June 1929* (Washington, D. C.: U. S. Government Printing Office, 1929), p. 108.

and cavalry.[77] In 1929, Congress approved $250,000 for the Army to build and test six Christie-type tanks, capable of traveling in excess of 40 mph, but Summerall only purchased one, deeming the vehicle too heavy for the EMF's needs.[78]

The maneuvers of 1930, deemed the "most interesting" of the entire period, revealed the strategic mobility of tank forces as they made the 90 mile march from Ft. Eustis, Virginia to Camp Lee in one day.[79] Of considerable interest were the different road formations allowing varying combinations of speed, control, and visibility from the air. Because the M1917's degraded dramatically with even limited operation, they traveled on tank carriers for strategic marches. It took one hour to load a tank company onto the carriers, and about a half hour to unload it.[80] The unwieldy carriers also had no cross-country capability, limiting the areas where tanks could be unloaded, and giving offensive forces dead weight to protect in the rear.[81]

The maneuvers tested the relative merits of armored car and aircraft reconnaissance, and the communications necessary to relay the information with sufficient speed. The limited area available to the EMF dictated the tactical dispositions of the cooperating forces, hindering much of the combined arms aspect of the maneuvers. Within this, the tank company generally consisted of three platoons of three fighting tanks each and a signal tank. It usually attacked in line formation with 100 yards separation between vehicles, allowing it to cover a 600 yard front. In action, tanks displayed limited ability to hold ground, but their striking ability supported by infantry

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[77]Ralph E. Jones, "The Tactical Influence of Recent Tank Developments" *Infantry Journal* (May 1928): 463.

[78]Gillie, *Forging the Thunderbolt*, p. 34.

[79]Arthur B. Wilson, "With the Mechanized Force on Maneuvers," *The Cavalry Journal* (July-August 1931): 6.

[80]U. S., War Department, *Infantry Field Manual Volume II, Tank Units*, (Washington, D. C.: U. S. Government Printing Office, 1931), p. 4.

[81]Wilson, "With the Mechanized Force on Maneuvers," p. 8.

proved effective. Mounted in an armored radio car, the force commander communicated with forward elements through observation aircraft by radioing messages to the aircraft, which in turn dropped messages to the tank elements.[82]

Radio communications, though vital to a mechanized force, had a degree of official prejudice to overcome. In one of the Divisional Exercises of 1927, wire and runners were preferred, but radio was deemed "no better than an expensive toy," and "within the infantry brigade was, as usual, of no value."[83] Cavalry units disdained using radiotelegraph for communication with aircraft, suggesting that observation planes use their otherwise worthless reel antennas to pick up messages.[84] Armor theorists, however, argued that a "highly developed and rapid system" based on "airplanes, and radio telegraphy and telephony" would be essential to control effective armored forces.[85]

In 1929, after a year of experimentation, communication in the EMF relied primarily on line, moved into the battle area by "wire reels . . . mounted on one of the track-laying cargo carriers."[86] Its employment with the square infantry division kept the EMF tied to static warfare, and heightened fears of signal security. All message traffic was accordingly encoded, adding more time to an already slow process. After encoding and decoding, radiotelegraph links among lower echelons averaged 25 minutes for a twenty word message.[87] Patton provided a suitable summary of the problems afflicting radio for the EMF: "Until some much more perfect and simple radio is available . . . it

[82]Ibid., p. 9.

[83]H. B. Fiske, "Maneuvers of the 2nd Division," *Infantry Journal* (September 1927): 234.

[84]John Hughes Stodter, "Communication Ground to Plane," *The Cavalry Journal* (April 1927): 292.

[85]Jones, "The Tactical Influence of Recent Tank Developments," p. 463.

[86]Levin H. Campbell, "A New Weapon of Warfare--the Mechanized Force," *Infantry Journal* (April 1929): 361.

[87]James D. O'Connell, "Signals," *Infantry Journal* (September-October 1931): 420.

seems doubtful if very much control can be exercised over such fast moving units as cavalry or mechanized forces."[88]

Army officials, when evaluating the experience with the EMF, made mostly sound conclusions. The obviously inferior equipment made basic lessons difficult to grasp, but as one correspondent to the *Cavalry Journal* put it, "Tactical doctrine should not be predicated on vehicles available; rather the place that mechanized forces will have in the army" should dictate weapons development.[89] General Summerall, while discouraged by the results, pointed to the capabilities of future tanks, which would be fast enough to avoid artillery and capable of forming the backbone of an offensive force. Reassuring the older arms, and foreshadowing American thought on armored warfare on the eve of World War II, Summerall stressed the importance of combined arms in any planned armored force.[90]

Major Sereno E. Brett, a prominent tank theorist, argued that lessons learned by the maneuvers should be reflected in tank organization. Brett mainly advocated increasing tank mobility, improving communication, and strengthening resistance to anti-tank units.[91] He gave communications among tank elements special attention, since it "requires no particular intelligence to determine the relative value of tank units controlled by radiotelephone...and similar units controlled solely by runners."[92] Brett watched the maneuvers featuring the British Army's Experimental Armored Force closely, especially its work with radio. He applauded its radiotelephone experiments, and was particularly impressed that select units had radios in every tank. The British provided other practical

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[88]George S. Patton, "The 1929 Cavalry Division Maneuvers," *The Cavalry Journal* (January 1930): 7-15.

[89]Wilson, "With the Mechanized Force on Maneuvers," p. 5.

[90]Summerall, "New Developments in Warfare," pp. 8-9.

[91]Sereno E. Brett, "Tank Reorganization," *The Cavalry Journal* (January 1930): 29.

[92]Ibid., p. 32.

guidance that many of those associated with the EMF noted, especially their use of short, prearranged signals, and their attempts at voice control. Adding these lessons to their own experiences, the EMF took steps to improve its ability to use radio to coordinate formations. Contributors to branch magazines called for two-way radio telephones in all tanks, the Tank Board requested new radio sets, and the Tank School required over 1,000 hours of radio instruction for its tank crew recruits.[93] Unfortunately, such improvements would never impact the Experimental Mechanized Force, whose independent status was in jeopardy in 1931.

Economic Depression, Radio Renaissance 1931-1934

In late 1930, however, official support made the EMF's prospects seem favorable. In one of his last orders as Chief of Staff, General Summerall made the Mechanized Force a permanent army formation under the command of Colonel Dan Van Voorhis. Some of the equipment still in Mechanized Force hands consisted of twenty-two light tanks, four motorcycles, and ten armored cars. One of the Franklin armored cars carried a radio for command purposes, and two tanks, an M1917, and a new T1E2, carried the SCR-78A.[94] Each of the two nine-tank companies could have a signal tank, and the commander could coordinate action from his armored radio car. Significantly, in March 1931, after over two years of existence, the Signal Corps finally began to organize an organic signal platoon for the unit's communication needs. The platoon's radio section was the most important, containing fourteen of the twenty-eight men assigned.[95] As yet

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[93]Eugene Ferry, "Ideas for a Tank," *Infantry Journal* (November 1930): 504.; C. C. Bensen, "Tank Divisions," *The Cavalry Journal* (January 1931): 17.; "Radio for Tanks," *Infantry Journal* (February 1931): 136.; Ralph E. Jones, "Our Tanks," *Infantry Journal* (January 1930): 48.

[94]Arthur Wilson, "The Mechanized Force, its Organization and Present Equipment," *The Cavalry Journal* (May-June 1931): 8-9.

[95]"Communication Personnel for the Mechanized Force," *Signal Corps Bulletin* (March April 1931): 55.

without Signal Corps support, Van Voorhis' small group of vehicles began conducting exercises in January, variously testing tank offensives, defensive actions, and cooperation with other arms.[96]

Most army leadership ignored the Mechanized Force, and the Infantry in particular, resented losing its tanks to another organization. External forces, too, were working against it. By 1931, the United States was in the throes of the Great Depression. The US Government, under President Hoover, sought to buoy the economy by cutting expenditures, and the military was a natural place to look for slack. General Douglas MacArthur, the new Chief of Staff, was under pressure to economize army organization. Citing the "inherent weaknesses and limitations" in the tanks themselves, and the "impossibility of having any considerable number" of machines available in an emergency, MacArthur disbanded the friendless Mechanized Force in May 1931.[97]

Even the nearly sacrosanct Air Corps suffered. The completion of its five-year building program, scheduled for July, was delayed until 1933.[98] The Air Corps rebounded in 1934 after its spectacular failure at carrying the nation's air mail. Public concern over the Air Corps' inability to accomplish what seemed to be a basic task prompted the Secretary of War to form the Baker Board. The board's conclusion resulted in a recommended 600 plane building effort over three years, and the formation of the GHQ Air Force in 1935.[99]

After MacArthur eliminated the Mechanized Force, he assigned the development of infantry support tanks to that arm, and charged the Cavalry to produce armored vehicles to enhance its performance in traditional roles such as reconnaissance, flanking,

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[96]Gillie, *Forging the Thunderbolt*, pp. 41.

[97]MacArthur, *Report of the Chief of Staff, 1931*, p. 43.

[98]U. S., War Department, Patrick J. Hurley, *Report of the Secretary of War: To the President, 30 June 1932* (Washington, D. C.: U. S. Government Printing Office, 1932), p. 39.

[99]U. S., War Department, George H. Dern, *Report of the Secretary of War: To the President, 30 June 1934* (Washington, D. C.: U. S. Government Printing Office, 1934), pp. 4-5.

and pursuit.[100] The infantry tank's organization and communication remained wedded to linear static warfare concepts. As specified by the Infantry's 1931 Field Manual for tank units, each infantry division contained an organic light tank company of 15 main line tanks divided into three platoons. The headquarters platoon had nine tanks, and functioned as tactical reserve for men and machines, maintained replacement supplies of gasoline and ammunition, and held the signal tanks for contact with division headquarters.[101] The main functions of the infantry tanks were to lead or accompany attacking foot soldiers, but the manual acknowledged the potential utility of fast tanks for exploitation of breakthroughs, or other independent uses.[102]

The Infantry's list of independent uses for tanks basically mirrored the traditional cavalry missions. The manual restricted radio to providing redundancy "in rear of the line," or non-combat related message traffic. All combat communication, including tank unit to command posts, tank unit to infantry, tank unit to subordinate machines, as well as inter-tank links, would be by visual signals or messenger.[103] These changes constituted a return to the World War I control system, with problems that were still apparent in 1931: "The operation of the individual tank and the direction of its fire are susceptible of regulation only from within the tank itself." Further, "It is with the greatest difficulty that the platoon commander will be able to gain control of his unit prior to the first rallying position."[104] Even so, radio had vanished from Infantry tank combat.

Fortunately, the Cavalry accomplished the bulk of armored doctrine experimentation. It absorbed the Mechanized Force as a reinforced cavalry regiment,

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[100]MacArthur, *Report of the Chief of Staff, 1935*, p. 43.

[101]*Infantry Field Manual, 1931*, p. 63.; *Army Organization and Organization of Signal Communication Units*, p. 26.

[102]*Infantry Field Manual, 1931*, pp. 181-182.

[103]Ibid., p. 202.

[104]U. S., War Department, *Army Extension Courses, Special Text 14: Tank Operations*, 1931 ed., (Washington, D. C.: U. S. Government Printing Office, 1931), pp. 20-21.

designated the "Detachment for Mechanized Cavalry Regiment," on 1 November 1931.[105] Most Cavalry leadership was not overly enthusiastic about its new responsibility, and mainly sought to reassure its ranks that the mechanized formation would not replace the horse nor remove them from horse duty.[106] In spite of this, the Mechanized Cavalry made marked progress both in tactical theory, and signaling organization. On 2 November, the former Mechanized Force began the move from Ft. Eustis to Ft. Knox, Kentucky, coordinated by seventeen motorcycle messengers. During the winter and following spring the new unit held daily drills and command post exercises. In April, the Chief Signal Officer visited Ft. Knox and assessed the signal needs for the force. By June, the unit's signal officer was sent to the Signal Corps laboratory to design a new radio for mechanized forces.

The resulting sets, the SCR-189 transmitter and receiver, and the SCR-190 receiver only, would be the first sets in the US Army to utilize the superheterodyne receiver. This had become possible after Edwin Armstrong's initial patents expired in 1931, allowing commercial construction of the sets.[107] Using the superheterodyne allowed sets to transmit at high frequency, making them the first short-wave sets widely employed by armored forces. The SCR-189/190 was designed for the M1917, and had an in-motion range of eight miles radiotelegraph, and three miles voice. The transmission range was between 2,200 kHz and 2,600 kHz, with a separation of at least 60 kHz between channels, if the communications nets were close together, and 10 kHz if they were a mile or more away. Thus, several operating frequencies could be accommodated, allowing more sets to work in close proximity. The transmitter used a 7.5 watt master

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[105]Robert W. Grow, "The Ten Lean Years: From the Mechanized Force (1930) to the Armored Force (1940)," pt. 2, *Armor* (March-April 1987): 25.; Major General Grow served as the S3 (Operations) for the EMF, and later commander the 6th Armored Division in WWII.

[106]"Mechanized Force Becomes Cavalry," *The Cavalry Journal* (May-June 1931): 5.

[107]Terrett, *The Emergency*, p. 30.

oscillator power amplifier circuit. Like all sets up to this time, tuning was manual, and the operator had to adjust both the antenna oscillator circuit and the transmitting oscillator circuit.[108] The SCR-189/190 became experimentally available in late 1933, and was distributed widely starting in 1934.

Even in 1932, however, Signal Corps officers realized that the low operating radius and limited number of available channels might be insufficient for faster tanks coordinated by complex radio nets.[109] Significantly, the SCR-189's range approximated that of the standard German tank set, the 10 W.S. While using approximately the same technology, the German set was superior in its ability to accommodate a large number of different nets. Not only were there two models calibrated to different transmission ranges, but the transmission frequencies themselves were in the 20-30 MHz range, designed to allow closer channel spacing.[110] The US Army's new tank sets, while decidedly better than the SCR-78A, were obsolete before they reached the field.

Also in June, the new unit was redesignated the 7th Cavalry Brigade (Mechanized), still commanded by Colonel Van Voorhis, and now joined by Lieutenant Colonel Chaffee.[111] The 7th Cavalry Brigade did not enjoy an auspicious beginning. The handful of experimental Christie tanks procured in 1932 were notoriously unreliable. Demonstrations held for government officials often featured broken-down equipment, and communications were so poor that, according to then-Major Robert Grow, the brigade's operations officer, "Observation and control was the greatest problem."[112] Through the daily exercises and demonstrations, Chaffee and his staff, with the advice of

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[108]TR 1210-70, Radio Sets, Types SCR-189 and SCR-190, September 11, 1934.

[109]H. C. Ingles, "Command and Signal Communication to and within Mechanized Units," *Signal Corps Bulletin* (September -October 1932): 10.

[110]Berger, *Communications Equipment of the German Army*, p. 142.

[111]Grow, "Ten Lean Years," pt. 2, pp. 25, 27-28.

[112]Ibid., p. 30.

Signal Corps experts, arrived at the basic signal organization used by lower-level tank units in World War II. The chief advances were moving the lowest level of radio control from the company down to the individual tank, and accepting the radiotelephone as the primary link between each command echelon. Specifically, "Adequate control of tanks requires two-way channels of communication at all headquarters to include the platoon. Within the platoon a one-way channel between the platoon commander and the separate tanks is sufficient."[113] The Army had finally arrived at the same conclusion as Guderian had in 1924: all tanks should be controlled by voice radio.

The need for radio as the primary link was predicated on the need for individual tank mobility, and between tank units and stationary headquarters. Voice was required because keying and recording radiotelegraph messages while traveling cross-country would prove prohibitively difficult.[114] Where the old communication system called for one two-way radio per tank company, the new organization provided three two-way radios and nine receivers.[115] The new organization still retained visual signals and messengers for redundancy. More significantly, it reaffirmed the static nature of divisional headquarters. Considerable progress toward a proper organization had been made, but until the new radios arrived, the mutual interference caused by this density of limited-channel sets would keep the command net difficult to use.

With the combat communication system outlined, the 7th Cavalry Brigade found further difficulties with the control of marching columns. The Brigade's first significant exercise inadvertently addressed this problem during the winter of 1932-1933. The 3,240 mile road march from Ft. Knox to Ft. Marfa Texas was notable, both for its successful vehicle maintenance, and for its poor command and control. Traveling in a lengthy

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[113]Ingles, "Command and Signal Communication to and within Mechanized Units," p. 2.

[114]Ibid., pp. 2, 7.

[115]Ibid., p. 7.; "Outline Organization, Cavalry Regiment (Mechanized), March 1932 (Tentative)," *The Cavalry Journal* (March-April 1932): 10.

column at twenty-five miles per hour required a scouting force of armored cars up to 100 miles in advance to reconnoiter the approach and choose the best route. In an ideal combat situation, the scouts would have been in constant radio contact with the column commander, but in this case, lack of suitable radios forced Van Voorhis to rely on motorcycle messenger, which was a "serious handicap" to column control.[116] Trying to remedy the problem with radio later in February, and again in March, Grow remarked, "radio left much to be desired," and, "radio not reliable...Advance guard distances and communications must be worked out."[117] By fall, these requirements had been largely accomplished.

In a 12-15 September exercise, the 1st Cavalry marched on Lexington, Kentucky sending out a reconnaissance team ten miles forward, covering every line of approach. Another advance guard patrolled five miles in front of the main column. The entire force was separated into two nets, employing for the first time in appreciable numbers, the new short-wave SCR-189/190's. The SCR-189's performance was "satisfactory," making the air "full of reports and commands, sending troops here and there to care for new developments."[118] The problems encountered can mainly be credited to the weather, as rain made the equipment damp and taxed the unskilled operators' ability to maintain them. Operator inexperience also left them too eager to switch from voice to telegraph if static interfered. As with any AM set, the engines and nearby power lines caused a significant portion of this static.[119]

The 7th Cavalry Brigade's most important training of 1934 took place during the Ft. Riley, Kansas, Cavalry Maneuvers. The Brigade equipment was only six new M1

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[116] William P. Withers, "Mobile Communication for Mechanized Cavalry," *Signal Corps Bulletin* (March-April 1934): 15.

[117] Robert W. Grow, "The Ten Lean Years: From the Mechanized Force (1930) to the Armored Force (1940)," pt. 3, *Armor* (May-Junel 1987): 21.

[118] Withers, "Mobile Communication for Mechanized Cavalry," pp. 24-25.

[119] Ibid., pp. 23-25.

tanks, eighteen representative cars to fill out the squadron, and a number of armored cars. As per the 1932 organization, communication would rely primarily on voice radio, backed up by motorcycle and armored car messenger.[120] While practicing for the exercises, Major Grow found the communications "excellent," and the organization "flexible and...easily adapted to fit the situation."[121] The first maneuver, occurring 4 May, found the Brigade on a reconnaissance mission opposing a brigade of horsed cavalry. Due to poor weather, the 7th's radios proved unreliable, and it had to depend on motorcycle and mounted messengers.[122] The second maneuver, occurring 7 May, was an approach engagement with the 2nd Cavalry (horse). For this exercise the weather cooperated, and the 7th executed a 30 mph approach march, skillfully coordinated by Colonel Chaffee by radio, and devastating to the mounted units. During the remainder of the Maneuvers, which concluded 22 May, the 7th Cavalry Brigade demonstrated good strategic and tactical mobility, solid radio control, and proficiency at cavalry-type missions.[123] The mechanized cavalry had established a credible reputation, but it was 1934, and the US Army still had not tested a formation of modern tanks equipped with sufficient radios.

One remarkable technical advancement also occurred during this period, the invention of frequency modulation. Edwin Armstrong filed four patents between July 1930 and January 1933, culminating his career-long effort to eliminate static from radio.[124] As discussed previously, static is actually a distortion of the radio wave's amplitude. Since the information of an amplitude modulated signal is carried in the

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[120]"The Cavalry Maneuvers at Fort Riley, Kansas, 1934," *The Cavalry Journal* (July-August 1934): 5.

[121]Grow, "Ten Lean Years," pt. 3, p. 24.

[122]"The Cavalry Maneuvers at Fort Riley," p. 8.

[123]Ibid., p.10-14.

[124]Lessing, *Armstrong,* pp. 193-196.

amplitude, any unintentional distortion becomes indistinguishable from the original signal. The only other characteristic of an electromagnetic wave that can be substantially varied is its frequency.[125]

Researchers had tried working with FM as early as 1903, when the Poulsen Arc made it possible to establish, and hence vary, a definite frequency transmission. Their efforts, however, were universally unsuccessful because AM signals work best when tuned to a precise frequency. For instance, with the SCR-189 transmitter, its operating frequency ranged from 2,200 kHz to 2,600 kHz; a difference of 400 kHz. Assuming a separation of 10 kHz, 40 channels would theoretically be available for communication without significant interference between adjacent channels. However, if the transmission frequency could be tuned more precisely, the separation could be reduced, allowing more channels in the same 400 kHz frequency range. Unlike AM, FM transmissions become distorted if confined to a precise, or narrow band, frequency. In fact, the wider the frequency variance, or bandwidth, the better FM signals suppress static.[126] As discussed earlier, the AM electromagnetic wave directly incorporates the audio signal into its amplitude: the amplitude of the audio signal determines volume, and its frequency determines pitch. For the FM wave, volume is established by the amount the frequency changes, and pitch is determined by the rate of change in frequency.[127] In other words, the louder a sound is, the more dramatic the change in frequency. The higher the sound, the more rapidly the frequency will change within the bounds set by the volume.

To produce frequency modulated waves, Armstrong required a "precise and controllable" method of varying frequency.[128] Though not Armstrong's invention,

[125]Ibid., p. 197.

[126]Ibid., p. 202

[127]John F. Rider, *FM: An Introduction to Frequency Modulation*, (New York: John F. Rider Publisher, 1940), p.4.

[128]Lessing, *Armstrong*, p. 206.

crystal-controlled tuning emerged as the answer. Prior to the invention of crystal oscillators, tuning was complicated and temporary. The regenerative circuit, designed to coax high-frequency oscillations out of the three-electrode vacuum tube, relied on a combination of an inductor and a capacitor to regulate the transmission frequency. Selecting a frequency, then, was a matter of adjusting the capacitance in the circuit. Similarly, the capacitance in the receiving circuit had to be adjusted to pick up the desired frequency. As a typical example, the SCR-130's tuning procedure involved tuning the transmitter and the receiver. Tuning the transmitter was relatively easy. The operator first set the desired frequency, then, with the help of an ammeter, adjusted the capacitance in the antenna circuit to achieve the maximum transmission current.

Tuning the receiver was slightly more complicated. First, the operator adjusted the main receiving capacitor until he heard a click in the headphones. He then turned the adjustment knob five degrees from the point where he heard the click, and then "fine-tuned" the signal, by adjusting the secondary capacitor circuit. Once the signal could be heard, a third capacitor further refined reception. Finally, the main capacitor was adjusted again to optimize the signal strength.[129] The real difficulty with manually tuning a radio was the frequency drift associated with the adjustable capacitor. Once set at a particular frequency, the capacitor-inductor circuit would gradually come out of adjustment. When frequency drift occurred in the transmitter and the receiver, tuning became a constant effort. Cross-country travel, of course, exaggerated frequency drift.

Crystal control offered an alternative. By including a quartz crystal in the capacitor-inductor circuit, the crystal oscillator circuit could experience a remarkably small frequency drift of 0.005 percent of the transmission frequency.[130] This stability

[129]U. S., War Department, *U. S. Army Training Manual No. 27: Radio Operator Instructors Guide, Pt. I Radio Sets,* (Washington, D. C.: U. S. Government Printing Office, 1927), pp. 260, 263-264.

[130]Milton S. Kiver, *F-M Simplified*, 3d. ed. (Princeton, NJ: D. Van Nostrand Company, 1960), p. 116.

comes from the physical properties of the crystal, since its perfectly uniform molecular lattice resonates at a predictable primary frequency, along with the full complement of harmonic frequencies. The crystal oscillator circuit was constructed by connecting a crystal across the mesh circuit of the three-electrode vacuum tube. A capacitor-inductor circuit designed to oscillate at a particular harmonic of the crystal is then placed across the plate circuit. Each frequency transmitted or received must have its own crystal and capacitor-inductor circuit. Exact tuning, therefore, became a function of activating the desired crystal circuit, accomplished by the simple push of a button.[131]

Armstrong based his mechanism for detecting frequency modulated waves heavily on his superheterodyne receiver. The devices are identical, except for the addition of two components, the limiter and the discriminator. As the high-frequency FM signal entered the receiver. Stages 1 and 2 heterodyned it to an intermediate frequency, and amplified the resulting signal. Stage 3, the limiter, filtered out any amplitude variations, thus removing static. Stage 4, the discriminator, converted the frequency variations to amplitude variations. Stages 5 and 6 detected the new AM signal and amplified it so that it could activate the speaker system. The resulting audio signal always emerged free of static, impervious to spark plug and tank track interference, and resistant to operator incompetence. Armstrong's frequency modulation system was demonstrated definitively in 1935.[132]

The SCR-189 and Mechanized Cavalry, 1935-1938

For the Army, FM was still some years in the future. The SCR-189 was a genuine improvement over previous models, and mechanized force commanders were happy to have finally received full complements of them. Unfortunately, the set's limited range,

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[131]Ibid., pp. 117-118.
[132]Lessing, *Armstrong,* pp. 114, 206.

and the interference associated with amplitude modulation, rendered the set inadequate for the missions mechanized cavalry wished to accomplish. The year 1935 represented a turnaround because it marked a renewed interest in mechanization from both the government and Army leadership. By 1938, the 7th Cavalry Brigade was fully equipped with the newer M1 combat cars, and through the largest exercises to this point in the United States, could finally see that better radio would be needed to coordinate highly mobile formations.

In 1935, his final year as Chief of Staff, General MacArthur remarked, "The present year definitely marks the beginning of a long-deferred resumption of military preparation on a scale demanded by the most casual regard for the Nation's safety and security."[133] The Secretary of War felt that "the motorization and mechanization of our armored forces is of primary importance."[134] The previous year witnessed the first large-scale procurement of tanks since the Great War. For 1935 Congress appropriated $ 2,119,200 specifically for tanks, and the following year approved $ 2,800,000 for radio equipment and another $3,496,000 for mechanization.[135] In all about 52 M1 tanks, originally designed in 1927, were ordered for the mechanized cavalry.[136]

In spite of the increased attention given to mechanization, Army officials still emphasized other areas that hindered work with mobile armored doctrine. For instance, procurement for the Army Air Forces really remained first priority. The 1936 appropriation for tanks pales in comparison to the $20,350,000 approved for aircraft

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[133]MacArthur, *Report of the Chief of Staff, 1935*, p. 41

[134]U. S., War Department, George H. Dern, *Report of the Secretary of War: To the President, 30 June 1935* (Washington, D. C.: U. S. Government Printing Office, 1935), p. 2.

[135]U. S., Congress, House, *War Department Appropriation Bill, Fiscal Year 1935: Report to Accompany H. R. 8471*, 73rd Cong., 2d sess., 1934, H. Rept. 869, p.23.; *War Department Appropriation Bill, Fiscal Year 1936*, p.6.

[136]U. S., War Department, Malin Craig, *Annual Report of the Chief of Staff, 1936*, in *Report of the Secretary of War: To the President, 30 June 1936* (Washington, D. C.: U. S. Government Printing Office, 1936), p. 37.

construction the same year.[137] Seven hundred more aircraft were procured in 1937, and plans for 1938 contained even more expenditure for aircraft. The Chief of Staff, General Malin Craig also seemed misguided as to the proper areas to emphasize. He sent a large percentage of the tanks ordered in 1935 to infantry support units.[138] Commenting on the Spanish Civil War, he noted, "The lessons of the current operations abroad confirm...that in the provision of tanks, emphasis should be laid upon a type of tank suitable for close support of the Infantry."[139] Even in 1939, General Craig continued to advocate infantry support, stating, "...our training indicates too great emphasis on detached and independent missions with a consequent disregard for hard-hitting supporting missions which have a direct influence on battle."[140] Craig also attached a great deal of importance to the anti-tank and anti-aircraft procurement, which received top priority through 1937 and 1938.[141] The result of this deflected emphasis was that army maneuvers showcasing independent mechanized forces were still underfunded.

The first such maneuvers of any importance, The Second Army Maneuvers, took place 5-22 August 1936 near Ft. Knox, Kentucky. The Mechanized Force, commanded by Colonel Bruce Palmer, included the 7th Cavalry Brigade (Mechanized), a battalion of mechanized field artillery, motorized infantry, and a flight of aerial observation craft.[142] The opposing force was larger, but less mobile. Generally, the Mechanized Force was tasked with containing its rival through delaying actions, flanking movements, and shock. The first exercise was a delaying action, during which the Mechanized Force displayed

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[137] *War Department Appropriation Bill, Fiscal Year 1936*, p. 6.

[138] Craig, *Report of the Chief of Staff, 1936*, p. 37.

[139] U. S., War Department, Malin Craig, *Annual Report of the Chief of Staff, 1937*, in *Report of the Secretary of War: To the President, 30 June 1937* (Washington, D. C.: U. S. Government Printing Office, 1937), p. 34.

[140] Marshall, *Biennial Report of the Chief of Staff, 1939*, p. 31.

[141] Craig, *Report of the Chief of Staff, 1938*, p. 33.

[142] "Mechanized Cavalry in the Second Army Maneuvers," *The Cavalry Journal* (November-December, 1936): 462.

characteristic proficiency with advanced patrol reconnaissance coordinated by radio. Rapid movement reduced the forward units' ability to send information rearward, and also hampered the effectiveness of radiotelegraph, due to the time required to code and decode messages.[143] The major operational glitch during the exercise was an improperly coded message that sent one of the armored columns in the wrong direction.[144] The second exercise was a well-coordinated, wide enveloping movement and flanking attack accompanied by attack aviation. The advance guard system continued to work well, and another successful frontal attack occurred the following day.

During this portion of the maneuvers, certain overriding communications problems emerged. The Mechanized Force's high cross-country speed limited the ability for the few observer aircraft to monitor the battlefield, and made dropped message communication too slow. A correspondent reported, "by the time the observer could write a message and drop it, the tanks had moved to another point."[145] Another major deficiency in the communication regime was the insufficient signal personnel. Signal Corps troops had to drive communications vehicles and operate the equipment during the maneuvers, and repair the equipment at night, forcing them to work around the clock. The corresponding decrease in efficiency could have been avoided had separate crews been provided to repair the sets.[146]

On 12 August, the troops moved to Allegan, Michigan for more exercises. Tactically, the Michigan Maneuvers contributed little to armored doctrine, since the Mechanized Force found itself being parceled out and employed "piecemeal."[147] The

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[143]Norman A. Nicolai, "Communication in the Second Army Maneuver," *Signal Corps Bulletin* (March-April 1937): 60.

[144]"Mechanized Cavalry in the Second Army Maneuvers," p. 465.

[145]Nicolai, "Communication in the Second Army Maneuver," p. 61.

[146]Ibid., p. 62.

[147]Robert W. Grow, "The Ten Lean Years: From the Mechanized Force (1930) to the Armored Force (1940)," pt. 4, *Armor* (July-August 1987): 36.

communications problems, however yielded some important lessons. The first was the difficulty caused by the wide assortment of radios fielded by the active, National Guard, and Reserve units, which would all be utilized in a rapidly mobilized army. The Mechanized Force also functioned flexibly with its SCR-189 radio net, although the AM sets still suffered from track static, especially on the new M2 tank. Moreover, while the Mechanized Force seemingly jeopardized security with excessive voice radio reliance, its code words and the rapid action made it irrelevant.[148] Overall, the quality of radio communication was "excellent," and "more successful than anticipated," even though the motorcycle messenger remained more dependable than radio, especially for relaying orders.[149]

The following year, the Army conducted another major exercise at Ft. Knox, in similar vein to the Michigan Maneuvers. Once again, the 7th Cavalry Brigade and some skeletonized supporting units were to take on a large horse cavalry detachment. To lend some appreciation to the real purpose of the exercises, Brigadier General Bolton, the commander of the 54th Cavalry Brigade (horse) exclaimed, "The exercise will go down in our history as the most valuable one we have ever had."[150] Official sentiments interpreted the maneuvers to reaffirm horse cavalry's place on the battlefield, since in the exercise area's wooded ravines and hollows, horse mounted troops proved invisible from the air, and inaccessible to tanks. Communications also suffered, since officials decided horse mounted messengers were the "most rapid and certain means" within two miles radius.[151]

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[148]W. S. Rumbough, "Signals in the Michigan Maneuvers," *Signal Corps Bulletin* (March-April 1937): 18, 26.

[149]Nicolai, "Communication in the Second Army Maneuver," p. 60.; "Mechanized Cavalry in the Second Army Maneuvers," p. 477.

[150]Willis D. Crittenberger, "Cavalry Maneuvers at Fort Knox," *The Cavalry Journal* (September-October 1937): 425.

[151]Ibid., p. 425.

Brigadier General Van Voorhis and his men continued to work without much support. In May 1938, to celebrate its full equipment with M1 tanks, the 7th Cavalry Brigade went on an extended road march to Georgia and back to Ft. Knox. Van Voorhis commanded the unit from the air by radio and dropped message. Once in Georgia, the 7th launched a successful mock night attack coordinated from the ground by radio and motorcycle. The following day, a mock daylight attack was mounted, again with favorable results.[152] The experiment with air-ground liaison found radio unreliable, as commented on by Colonel Patton, then with the Cavalry School: "in addition to [radio's] peculiar idiosyncrasy of stopping at important times, the presence of enemy radio will exert a very cramping influence through jamming." Again, somewhat more sarcastically, unlike with radio, "due to gravity, dropped messages always arrive."[153] For command on the move, however, radio was indispensable. The Brigade's success was largely due to its "efficient radio system which does not require a halt of five or ten minutes for a set up; instead the radios are continuously in operation"[154]

The Mechanized Cavalry Field Manual of 1938 reflected both the experience gained during the formation's six years of existence, and the integral role voice radio played in armored force deployment. Within the mechanized regiment, combat cars were to furnish offensive striking power through their inherent fire power, mobility, and protection. Their employment would not be independent, but reliant on close cooperation with supporting artillery, reconnaissance, and infantry.[155] Control and coordination of these units would be primarily by voice radio, which "most closely approximates

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[152]"The Mechanized Cavalry Takes the Field," *The Cavalry Journal* (July-August 1938): 291-295.

[153]Ibid., p. 296

[154]Ibid., p. 299.

[155]U. S., War Department, *Cavalry Field Manual: Mechanized Elements* (Washington, D. C.: U. S. Government Printing Office, 8 April 1941), p. 106.

fulfillment of the need of mechanized units."[156] Since static still hindered communications, vehicles were encouraged to halt, and avoid other vehicles or commercial power stations when sending and receiving messages.

The communications net for the mechanized brigade was based on mobile headquarters, and reflecting the 1932 organization, the division headquarters was still stationary.[157] The practical traffic limit for an individual net was six radios. After this number efficiency dropped off dramatically. The available sets, however, limited the number of nets that could be used, resulting in serious crowding during operations. Motorcycle messengers still supplemented voice radio, indicating radio's persistent tendency to malfunction during action. Fortunately, the Signal Corps had completed work on a new radio set, the SCR-210/245. The new sets addressed the two major problems plaguing operations with the SCR-189, namely the limited operating radius and frequency range. For voice radio, the new manually-tuned sets enjoyed an effective radius of 20 miles stationary and 15 miles in motion. The transmitters broadcast on a range of 2,000 to 5,250 kHz, and received everything between 1,500 and 18,000 kHz.[158] The SCR-210/245 made radio communication for armored forces practical, and remained in widespread operation in the US Army throughout World War II.

General Chaffee would be responsible for applying and testing the principles set down in the 1938 training manual. His first major opportunity came in August 1939 during the First Army Maneuvers in Plattsburg, New York. On 21 and 22 August, two exercises occurred simultaneously. Taking advantage of the SCR-245 for the first time, the results highlighted the mobility and striking power of mechanized forces, as well as

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[156]Ibid., p. 126.

[157]Ibid., p. 126.

[158]U. S., War Department, *Radio Sets, SCR-210 and Radio Sets SCR-245, Technical Manual 11-272* (Washington, D. C.: U. S. Government Printing Office, 23 February 1942), p. 5.

their vulnerability to infiltration by ground forces at night.[159] The second exercise, held 23-25 August, revealed the strategic mobility available if night marches were attempted, and the necessity of adequate reconnaissance to proceed movement. Overall, the maneuvers were instructive, highlighting the need for "constant combined training," and cooperation with "those missions of mobile combat most important to the success of the army."[160] The Mechanized Cavalry Brigade's combined arms support and reconnaissance constituted its chief advantage over infantry tank formations.[161]

After his impressive performance in the 1939 exercises, Adna Chaffee was promoted to Brigadier General, and placed in charge of the 7th Cavalry Brigade on 1 October. Unfortunately for Chaffee, the future status of the 7th Cavalry Brigade still remained in doubt because of the recalcitrant attitude of the Chief of Cavalry, Major General John K. Herr. The War Department decided to establish a mechanized cavalry division in April, but intended to transfer the necessary personnel and equipment from horse units. General Herr, who favored returning the saber to field use, reportedly challenged that the War Department "would take a single horse soldier away over his dead body."[162] Mechanization would continue without the support of the Chief of Cavalry, and ultimately without the Cavalry itself. Chaffee's expertise, influence, and drive made him an ideal candidate for the leadership of the Armored Force when Chief of Staff General George C. Marshall authorized its formation in 1940, in spite of General Herr's protestations.[163]

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[159]Terrett, *The Emergency*, p. 139.; Adna R. Chaffee, "The Seventh Cavalry Brigade in the First Army Maneuvers," *The Cavalry Journal* (November-December 1939): 452.

[160]Ibid., p. 460.

[161]Terrett, *The Emergency*, p. 141.

[162]John K. Herr, Quoted in Grow, "Ten Lean Years," pt. 4, p. 39.

[163]Ibid., p. 39.

FM Radio and the Prewar Maneuvers

The darkening cloud over Europe failed to concern the American public, but the German aggression of 1 September 1939 alerted government and military officials to the immediate possibility of war. President Roosevelt declared a state of Limited National Emergency on the 8th, and authorized enlisting another 17,000 men. These latter troops facilitated the army's change to the Triangular Division organization, which was completed 31 January 1940.[164] The fall of the Low Countries, and the eminent French collapse, however, prompted Roosevelt to recommend the tremendous sums of money for mobilization, and by the end of May, Congress began mobilization in earnest.[165]

The Army planned Spring Maneuvers for April and May based on the 1939 Tentative Field Service Regulations (FM 100-5). The exercises intended to test "the basic unit of the combined arms, the infantry division . . . represented by four brand new triangular divisions."[166] Like the 1923 version, the 1939 (Tentative) FSR still stressed the importance of combined arms, and still held that the infantry possessed the "principal mission in battle," and would accomplish its mission through fire, movement and shock action in close combat.[167] For 1939, planners felt confident enough to add the light machine gun to infantryman's traditional rifle and bayonet. The motivation behind the triangular division was to "reduce personnel, eliminate overhead, utilize modern motorization and weapons developments to the utmost, and relegate all non-essentials to rear echelons."[168] The triangular division was readily divisible into balanced combat

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[164]Marshall, *Biennial Report of the Chief of Staff*, pp. 4-5.

[165]Marshall, *Biennial Report of the Chief of Staff*, p. 6.

[166]William M. Grimes, "The 1940 Spring Maneuvers," *The Cavalry Journal* (March-April 1940): 98.

[167]*FM 100-5 1939 (Tentative)*, pp. 5-6.

[168]Grimes, "The 1940 Spring Maneuvers," p. 100.

units with attached artillery and engineers, and each division possessed enough transportation for about half of its troops.

Infantry tank units, still organized on the 1923 model, provided shock action to "assist the rifle units in dealing with organized resistance."[169] In special circumstances, tank units might operate as a powerful maneuvering offensive force, capable of exploiting a breakthrough. The FSR recognized that tanks required freedom of action, and could not be tied too closely to foot troops. The 7th Cavalry Brigade (Mechanized) was to represent "the light, fast, mobile ground elements of the Army," executing traditional cavalry missions.[170] No independent armored formation existed, but the FSR stressed maneuver warfare on the German model. Offensive action relied on the diversionary envelopment combined with a decisive penetrating blow.

Communication philosophy for the new organization made an important step toward the adjustment enabling radio to coordinate mobile armored warfare. The triangular division would still have a stationary headquarters, and radio communication in units larger than the division was to be considered only in an emergency. However, commanders could operate from a mobile command post with a primary radio link to their headquarters. For links between aircraft elements, mechanized forces, cavalry, and their headquarters "radio communication becomes the principal and often the only means."[171] Reliance on visual signal and messengers had receded further into the background.

The combined arms practice with corps and army-size units planned for the Spring Maneuvers would be the first since the Great War. The Fort Benning, Georgia area exercises took place from 14-27 April, and the larger Sabine Area (Louisiana and

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[169]*FM 100-5 1939 (Tentative)*, p. 6.

[170]Ibid., p. 9.; Grimes, "The 1940 Spring Maneuvers," p. 99.

[171]U. S., War Department, U. S. Army, *Signal Corps Field Manual: Missions, Functions, and Signal Communication in General* (Washington D. C.: U. S. Government Printing Office, 1940), p. 88.

Texas) Corps maneuvers from 8-25 May. Since portee horse cavalry still existed and held considerable support within the army, one of the exercise's intentions was to test the relative mobility of armored and horse troops in the two river-crossed areas. The handling of corps-size formations also received attention, particularly security concerns involved with coordinating the concentration and advance of such large bodies of troops. Perhaps the most obvious requirement for the new organization and increased combined arms emphasis, was the need for rapid orders distribution.[172]

The 51st Signal Battalion, the unit charged with communications for the maneuver, and its SCR-210/245 radio nets proved inadequate for the task. "The rapid movement of troops, widely separated units, and frequent movements of command posts . . . placed an undue strain upon the limited personnel and equipment of the battalion."[173] Wire communication became difficult to maintain, shifting the main communications burden at the corps level to available radio links. While an improvement over the old SCR-189, the new radios were "still unreliable for the distances encountered," and the need for manual tuning combined with the large number of nets overwhelmed the system.[174] Even with its large frequency range, the SCR-210/245 accommodated large numbers of nets with difficulty because of the frequency drift associated with manual tuning. Command and control also suffered because Army officials failed to anticipate the need for radio communication at levels higher than the division.

Tactically, General Chaffee's 7th Cavalry Brigade demonstrated decisive superiority over the opposing horse cavalry, and sealed exercise umpire George Patton's conversion to mechanized warfare.[175] The experiences gained during the Maneuvers,

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[172]Edgar L. Clewell, "Signal Communication in Fourth Corps during the Spring Maneuvers," *Signal Corps Bulletin* (July-December 1940): 27.

[173]Ibid., p. 30.

[174]Ibid., p.. 31.; Terrett, *The Emergency*, p. 141.

[175]Blumenson, *Patton Papers, Vol. 1*, p. 950.

coupled with Franc's dramatic defeat in June precipitated the creation of the Armored Force on 10 July 1940, with Major General Chaffee as its head.[176] The new force consisted of two armored divisions and a General Headquarters Tank Battalion. Though not granted the status of a combat arm, the Armored Force would be in charge of its own schools, replacement system, tactical doctrine formulation, and training.[177] Almost simultaneously, the General Headquarters (GHQ) was established in Washington to supervise the training of America's combat forces. The Armored Force would figure prominently in the GHQ Maneuvers slated for the following summer.

The Armored Force Field Manual, FM 17, contained the doctrines governing the Armored Force's employment. The most important change from the 1939 (Tentative) FSR allowed the Armored Force to act in conjunction with motorized infantry and cavalry or independently. Tanks could be employed in three different manners: they could lead the advance, followed by holding infantry, and exploited by a tank reserve; infantry could lead the advance, followed by exploiting tanks; and finally, tanks could cooperate with infantry in a combined assault. The subsequent final version of the Field Service Regulations, issued in January 1941, reflected the decline of the Infantry, which now would only play a primary role if circumstances required.[178]

Command and control would be accomplished by radiotelephone to a degree not yet embraced by the Army. The following statements reflect the importance and pervasiveness of radio links: "Voice radio enables the commander to exercise the force of his personality and to control the actions of his subordinates in considerable detail," and "The tactical mobility of an armored division is largely dependent on speedy inter-

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[176]Percy G. Black, "The U. S. Armored Force: The Possibilities of its Srategical and Tactical Employment," *The Cavalry Journal* (September-October 1940): 401.

[177]Kent Roberts Greenfield, Robert K. Palmer, Bell I. Wiley, *The Organization of Ground Combat Troops*, United States Army in World War II (Washington D. C.: Office of the Chief of Military History, Department of the Army, 1947), p. 57.

[178]*FM 100-5 1941*, p. 5.

communication."[179] To address the security concerns, only officers could operate voice radio, presumably intended to ensure professionalism and strict discipline on the air. Like in the German army, commanders were encouraged to stay far forward when coordinating their battles. The Armored Force had finally broken free from stationary headquarters.

The GHQ Maneuvers of 1941 tested the new organization and doctrines improvised during the previous two years. The exercises were divided into two phases. The Louisiana maneuvers took place between 15 and 24 September, and the Carolina maneuvers of 16-27 November.[180] Tactical work further refined the role of the Armored Force by reemphasizing the importance of combined arms. Because of the success of anti-tank forces, planners decided that tank units needed more infantry and artillery support, and decided by the end of 1941 not to grant the Armored Force an independent status on par with the GHQ Air Force.[181] The amended Armored Force Field Manual for 1942, FM 17-10, specified that armored forces had to "cooperate with combat aviation and large units of ground forces."[182] Command practices moved even closer to German models, including a new emphasis on decentralized control and individual initiative facilitated by better communications. The Army also made a final break with World War I attrition strategy by adopting strategic paralysis. Optimal results would now require "grouping of overpowering masses of armored units and launching them against vital objectives deep in the hostile rear."[183]

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[179]Ibid., pp. 2, 48.

[180]Christopher R. Gabel, *The U. S. Army GHQ Maneuvers of 1941* (Washington D. C.: Center of Military History, U. S. Army, 1991), p. viii.

[181]Greenfield, *The Organization of Ground Combat Troops*, p. 72.

[182]U. S., War Department, U. S. Army, *Armored Force Field Manual: Tactics and Techniques, FM 17-10* (Washington D. C.: U. S. Government Printing Office, 1942), p. 1.

[183]Ibid., p. 3.

While the doctrinal adjustments made during the GHQ Maneuvers contributed substantially to the US Army's eventual success in World War II, the communications progress is much more relevant to this study. Unlike the February 1940 Tennessee Maneuvers which found Patton's 2d Armored Division with only 14 percent of its radios, all forces in the GHQ Maneuvers were provided ample communications equipment of the most recent design.[184] Also for the first time, FM radios found their way into tank forces. Discussion regarding FM's employment began at Ft. Knox on 13 November 1939. The Signal Corps staged a five-day conference with members of the 7th Cavalry Brigade and representatives of other arms, to discuss their needs for FM equipment. The Signal Corps applied the characteristics and basic principles established at this meeting to produce the SCR-500 series vehicular radios that first became available in 1942.[185] Between 1939 and 1942, however a debate in government circles questioned the advisability of fielding FM radio. The chief issue was the availability of crystals, which the government had classified as a strategic material.[186] FM sets required a separate crystal for each preset channel, meaning that each radio would require as many as ten precision-cut crystals.

The success of radios during the Carolina portion of the maneuvers solidified the case for FM through popular acclaim. The 2d Armored Division used an improvised FM set based on a two-way police radio. Later designated the SCR-293, these sets equipped the US armored forces on its maneuvers until the SCR-500 series was distributed to troops along with the new M4 Medium tank in November 1942.[187] The SCR-508, 528 and 538's operated between 20.0 and 27.9 MHz with 80 possible channels and 10 push-button preset channels. The radios also employed an advanced "squelch" noise

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[184]Donald E. Houston, *Hell on Wheels: The 2d Armored Division* (San Rafael, CA: Presidio Press, 1977), p.71.

[185]Grow, "Ten Lean Years," pt. 4, p. 41.

[186]Terrett, *The Emergency*, p. 147.

[187]Ibid., p. 147.; Houston, *Hell on Wheels*, pp. 99, 111.

suppression system that made voice communication was possible out to ten miles with only 30 watts of power output.[188] The US Army had fielded radio technology a full ten years ahead of that possessed by any other belligerent, and coupled it with a highly effective communications organization ideal for mobile armored warfare.

[188]U. S., War Department, *Radio Sets, SCR-508, SCR-528, and SCR-538, Technical Manual 11-600* (Washington, D. C.: U. S. Government Printing Office, 25 March 1943), pp. 9-10.

CONCLUSION

The German Army decided to equip all of its armored vehicles with radios by 1924, before short-wave radio was available, and almost ten years before Edwin Armstrong had invented frequency modulation. Since Guderian did not formalize *Panzer* division organization until 1935, the Germans saw the need for radio control even before they formalized a working armored doctrine, and before suitable equipment existed. What existed, however, was the forward command concept and traditional reliance on the field commanders' individual initiative. To mesh this command and control doctrine with internal combustion-powered vehicles required instantaneous radio communication. The Germans embraced the new technology as a way to continue a traditional command philosophy.

British work with mobile armored forces during this period initially looked promising. The theories of Fuller and Liddell Hart discarded attrition warfare, and sought to utilize the tank in a novel, strategic manner. By 1924, the British Army ordered its first postwar tank radios, and fully equipped its tanks by 1928. In 1926, the General Milne's of Fuller's theories caused the creation of the Experimental Mechanized Force for testing strategic employment techniques for tanks. The Army Manoeuvers of 1927 garnered world attention, and even resulted in the American creation of its own experimental armored unit.

Underneath, however, the Army's traditionalism and the public's fascination with air bombardment conteracted whatever progress had been made. The 1927 Manoeuvers' success frightened the traditional arms and caused Milne to disband Experimental Armored Force the following year. The radio equipment designed in 1924 was the last British tank forces would see until the Expeditionary Force was hastily sent to France in

1939. At that time, British tank forces employed short-wave AM sets of 1935 design, and a linear organization and communication system established in 1925. Broad's work with the radiotelephone between 1931 and 1934 was largely ignored by Army leadership. His vintage equipment, with its static, and frequent breakdowns, was not accepted by the rank and file. Even the better short-wave equipment was regarded with suspicion for its potential to betray location to the enemy. More importantly, the British people had no desire to fight another war in Europe, and as late as February 1939, had no intention of doing so.

This lack of clear mission left the British Army with essentially the same land doctrine it used in the Great War. After 1928, there was not even a coherent effort to work towards a doctrine that accounted for the technological changes that had occurred. In this context, radio use seems like the least of the British Army's difficulties. Since the Army and public never appreciated the internal combustion engine's implications for land warfare, it could never achieve a doctrine to adjust to the new reality, and hence could not develop the equipment to make that doctrine practical. The selective attention given to the air threat only acknowledged half of the problem presented by German innovations.

The American experience looked much more dismal until the mid-1930's. The public sentiment against European involvement, its penchant for stringency, and the economic crisis of 1929-1933, left the US Army scraping by on its war surplus until 1935. Public impatience with the military left only enough popular curiosity for air power, whose advocates pressed just as insistently as their British counterparts for funds and independent status.

Questions about the future role of the tank seemed silenced after the Tank Corps was dissolved in 1920; for the Infantry had no intention of employing the tank for any mission that might cast doubt on the foot soldier's supremacy. In 1927, however, Dwight Davis decided to create the EMF after viewing the British maneuvers, and the dialogue

was reopened. The EMF had to accomplish its meager results with World War I radios and tanks, and in 1931, even the small interest in mechanization diminished when MacArthur disbanded the new unit.

The year 1931 was a turning point, for even if the Infantry abandoned tank radio control, deeming it unnecessary for infantry support, the formation of the 7th Cavalry Brigade (Mechanized) in November heralded a new direction for US armored forces. Using armored vehicles for cavalry missions required radio control, and in 1932, the 7th Cavalry Brigade decided that all tanks needed radio. By 1934 it had its first new radio set, which compared favorably with the German set developed for war use. The limited networking capability of the new set when mated with the 1938 tank models emphasized the complexity of armored force communication systems, and prompted efforts to improve the equipment.

The approach of war in 1939 began to awaken the Army in other ways. The infantry finally discarded the square division, began to use the streamlined triangular division, and contemplated independent uses for mechanized cavalry. The divisional headquarters, however, remained stationary. The inauguration of the Armored Force in July 1940 finally eliminated this vestige of linear static warfare, allowing division-sized units to operate freely with the commander's will. After extensive exercises in 1941, the Army decided to combine the Armored Force tank units and other arms more closely, reaffirming the Army's traditional combined arms emphasis. Frequency modulated radio, first adapted from civilian technology in November 1941 became the decisive coordinating force behind the US Army's combined arms success in World War II.

The United States Army suffered from many of the same maladies as its British counterpart. However, the American people found a ground war in Europe more conceivable then the populace of Britain, and discarded exclusive reliance on air power to ward off Hitler's Germany. The United States also seemed more willing to innovate and

borrow ideas from civilian as well as foreign military professionals. While its superior resources and extra time gave it an advantage in using FM radio, the Army's openness to new technology, and ability to envision its potential advantages for doctrinal application were greater benefits. Its organizational flexibility made it more willing than the hidebound British military to adapt to the challenges posed by the Germans and the internal combustion engine.

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